# ASTRONOMY

October 1984
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## How to Choose a Deep-Sky Telescope

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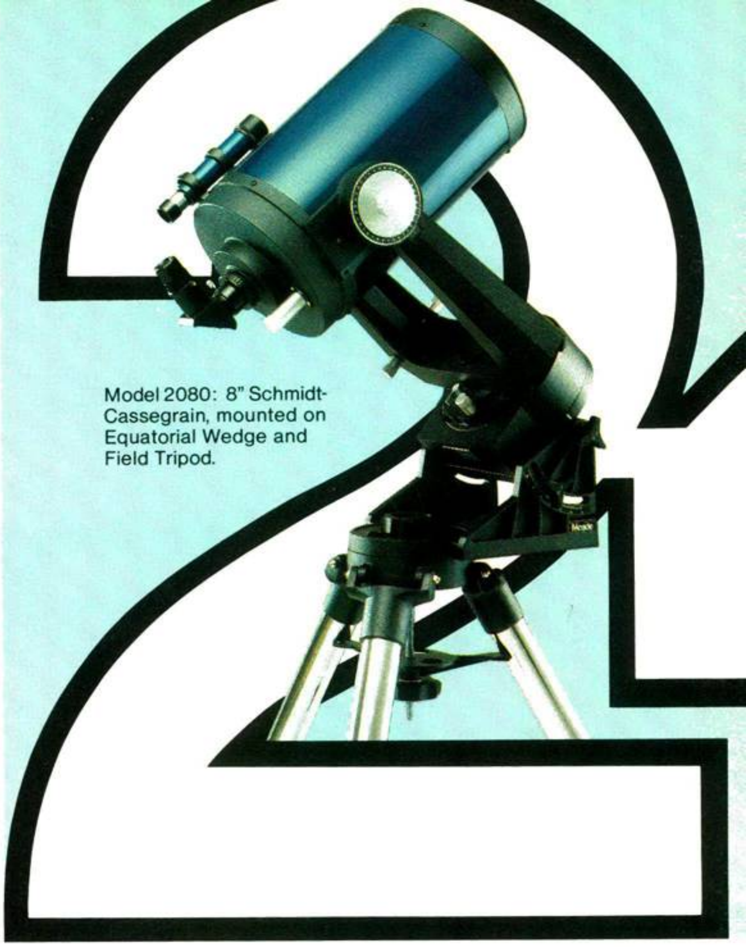
Meade Schmidt-Cassegrain Telescopes: **(1)** 4" Model 2044, with standard-equipment table tripod; **(2)** 8" Model 2080; **(3)** 10" Model 2120.



Model 2080: 8" Schmidt-Cassegrain, mounted on Equatorial Wedge and Field Tripod.

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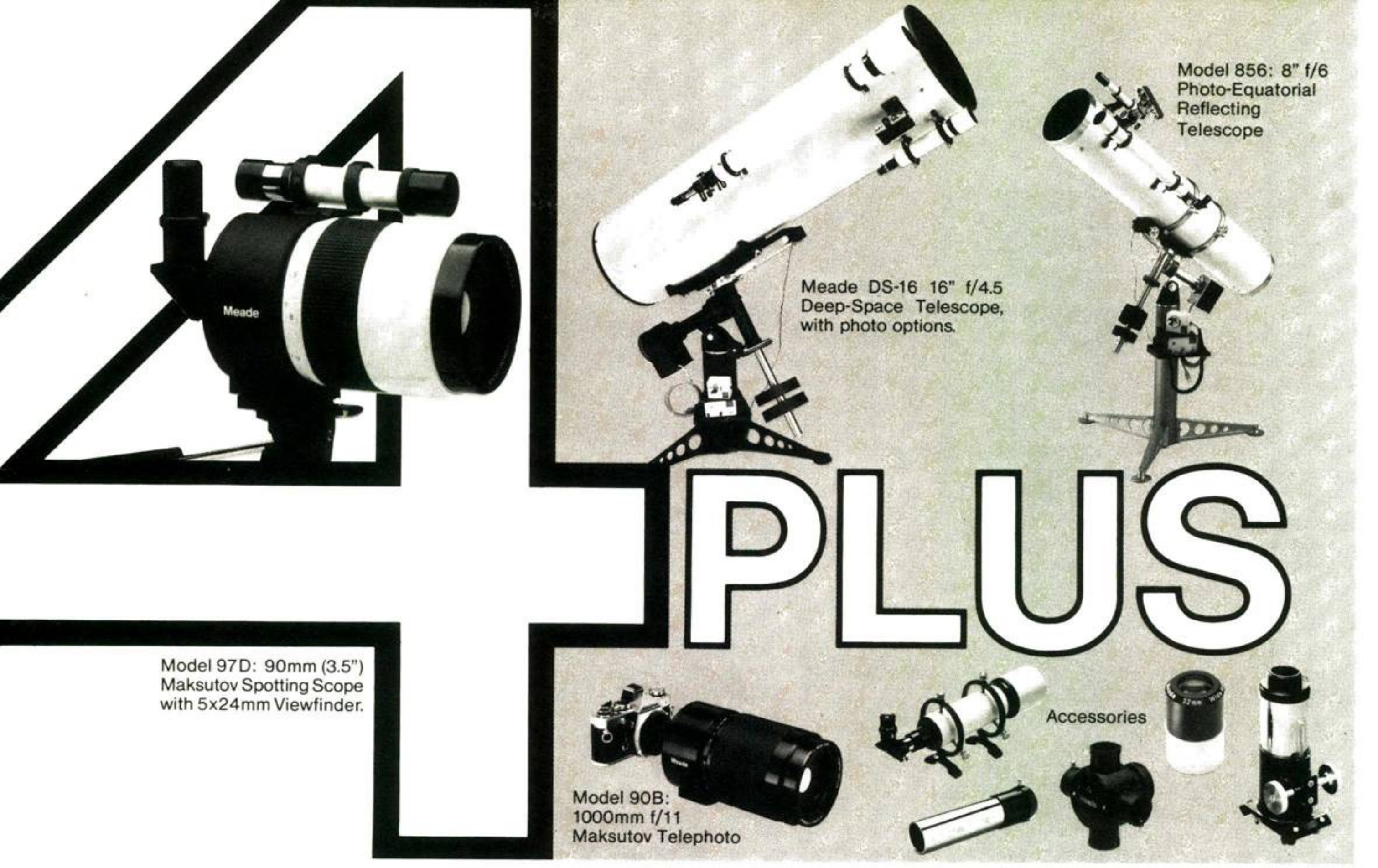

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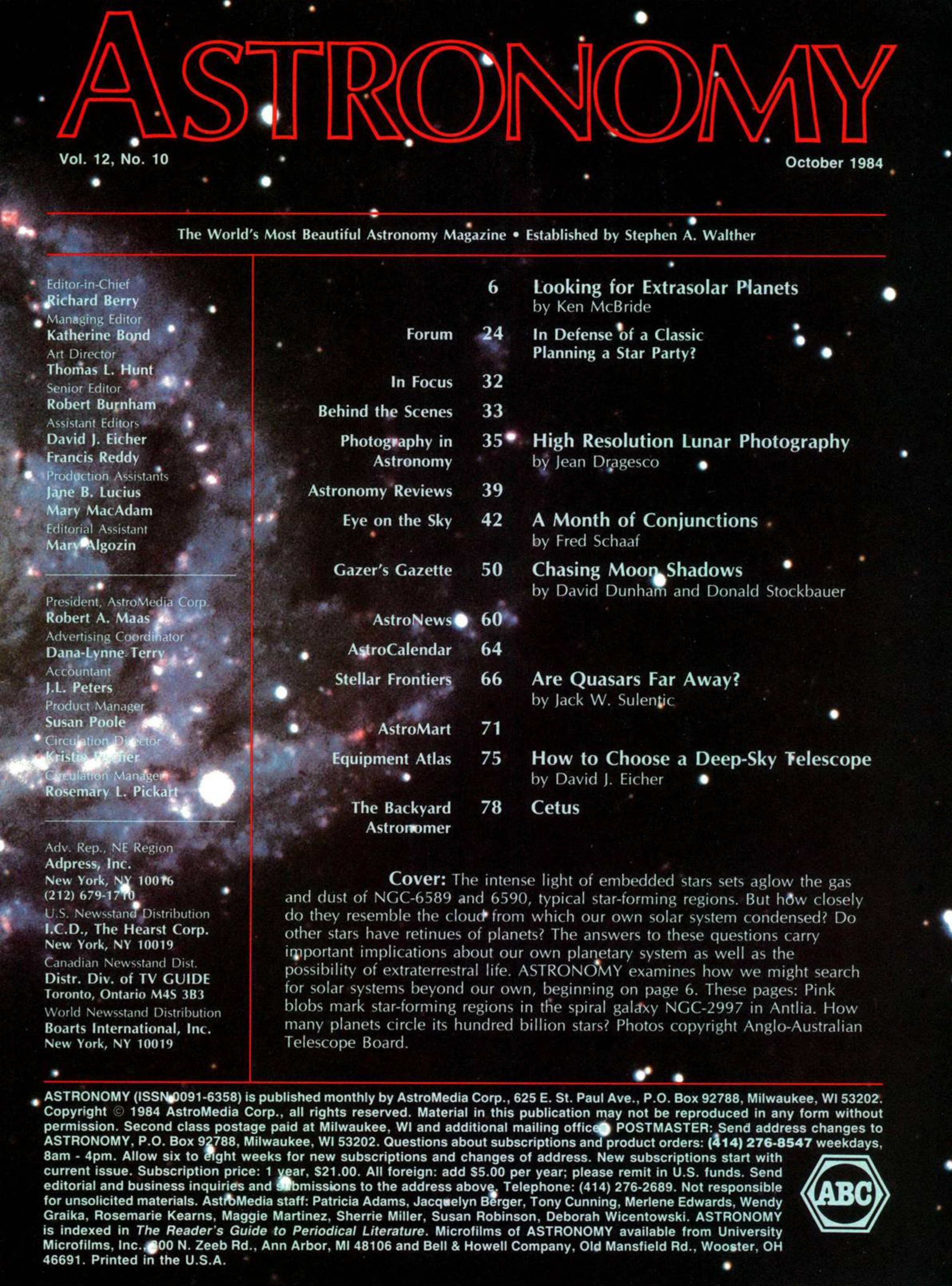

# ASTRONOMY

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**Cover:** The intense light of embedded stars sets aglow the gas and dust of NGC-6589 and 6590, typical star-forming regions. But how closely do they resemble the cloud from which our own solar system condensed? Do other stars have retinues of planets? The answers to these questions carry important implications about our own planetary system as well as the possibility of extraterrestral life. ASTRONOMY examines how we might search for solar systems beyond our own, beginning on page 6. These pages: Pink blobs mark star-forming regions in the spiral galaxy NGC-2997 in Antlia. How many planets circle its hundred billion stars? Photos copyright Anglo-Australian Telescope Board.

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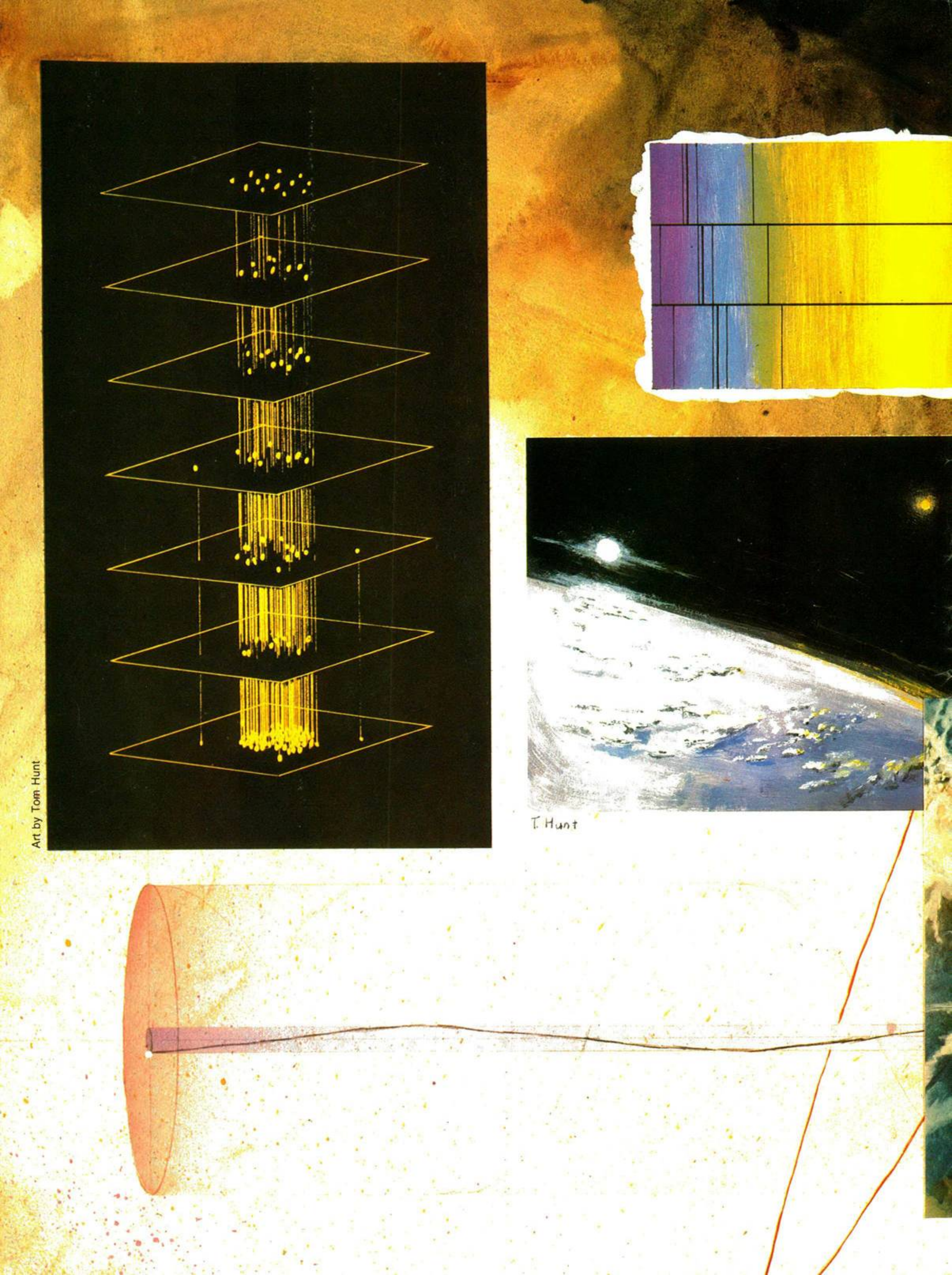
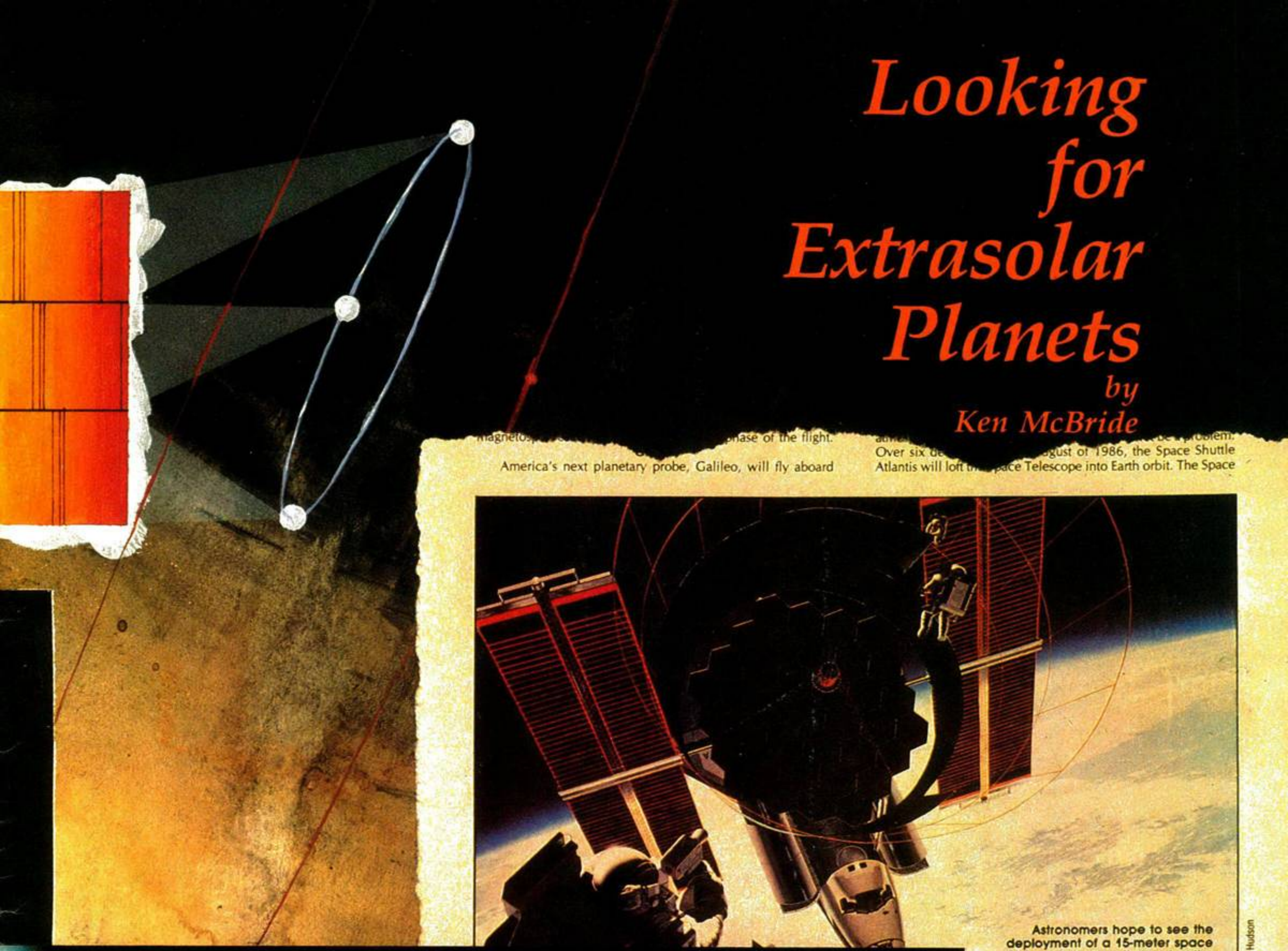


Art by Tom Hunt

# Looking for Extrasolar Planets

by Ken McBride


magnetos... phase of the flight.
America's next planetary probe, Galileo, will fly aboard
Over six de... ugust of 1986, the Space Shuttle
Atlantis will loft th... pace Telescope into Earth orbit. The Space
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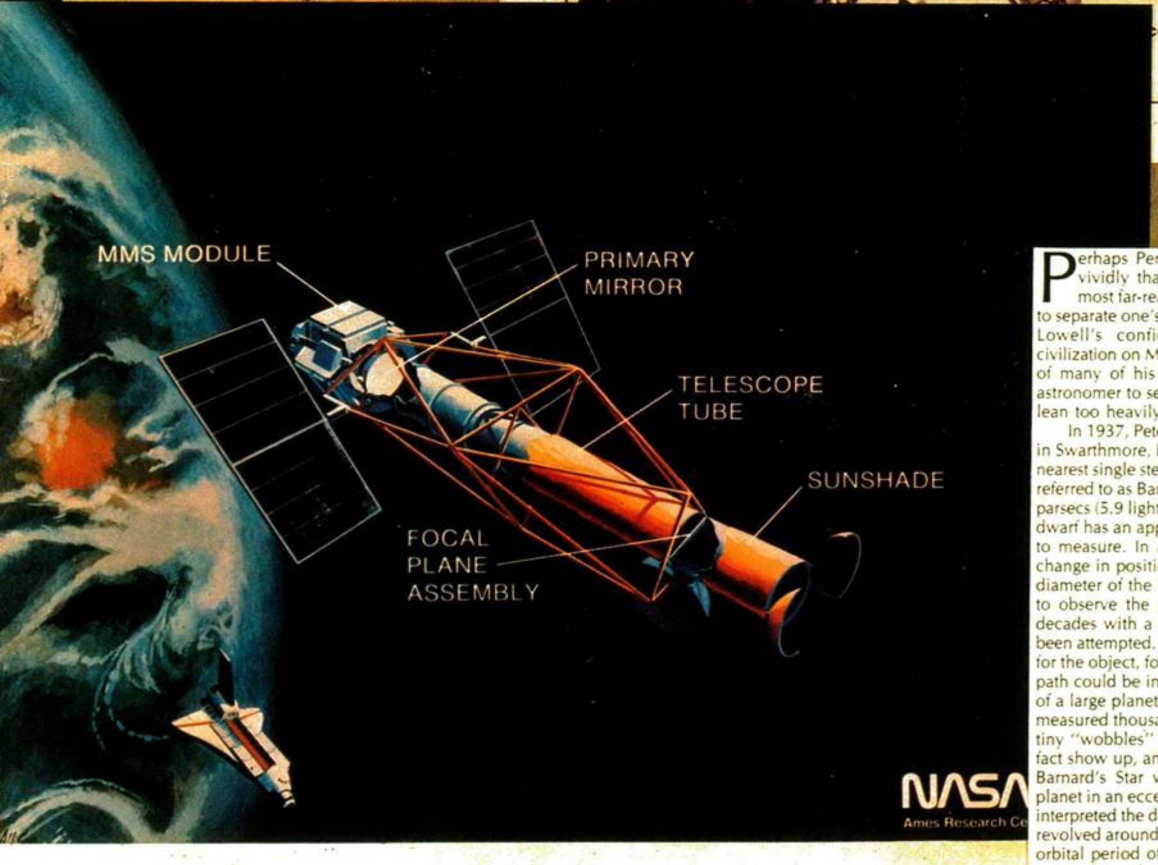
Astronomers hope to see the deployment of a 15-meter space telescope before the end of the century. It is perhaps the most ambitious plan for Shuttle-based astronomy.

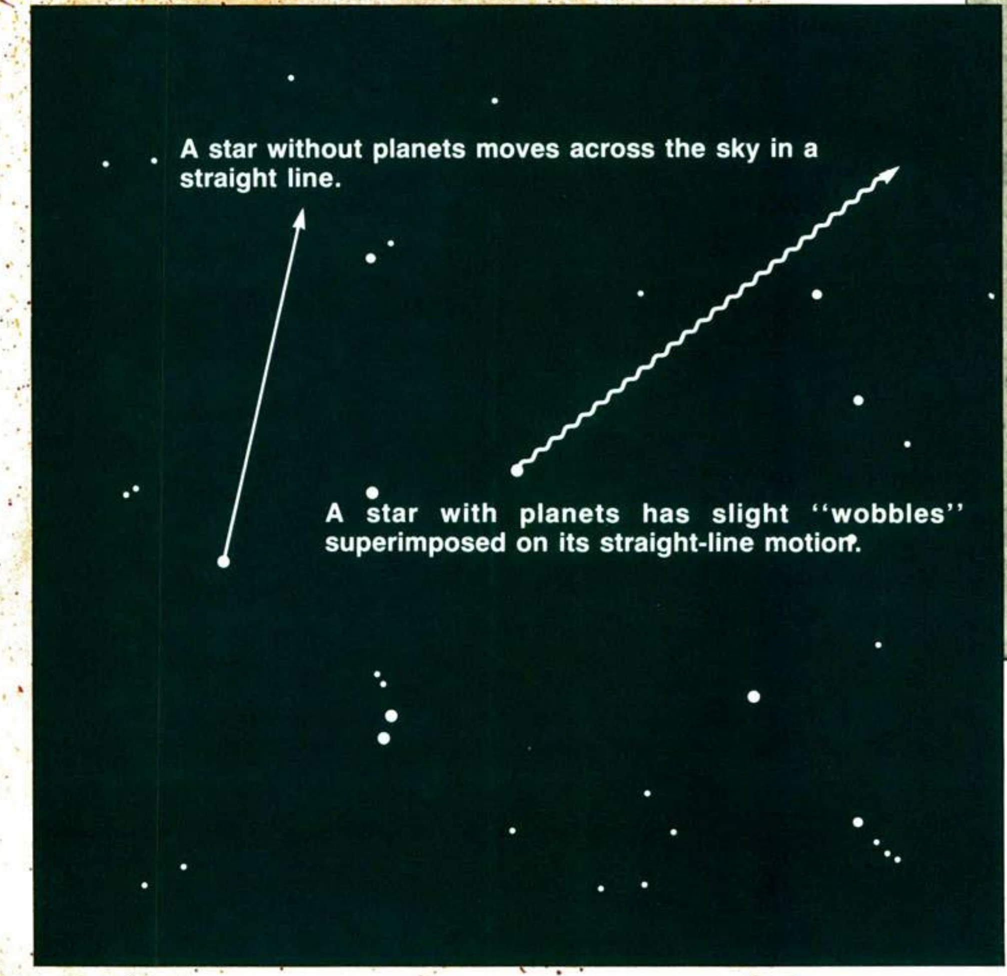
NASA art by Paul Hudson


MMS MODULE
PRIMARY MIRROR
TELESCOPE TUBE
SUNSHADE
FOCAL PLANE ASSEMBLY
NASA
Ames Research Ce

Perhaps Percival Lowell illustrated the point more vividly than anyone else: when dealing with the most far-reaching scientific questions, it can be hard to separate one's science from one's imagination. Indeed, Lowell's confident prediction of a technological civilization on Mars was actually consistent with the views of many of his contemporaries. He was not the only astronomer to see the canals, nor has he been the last to lean too heavily on his preconceptions.

In 1937, Peter van de Kamp of the Sproul Observatory in Swarthmore, Pennsylvania, began a study of the Sun's nearest single stellar neighbor, Munich 15040 — normally referred to as Barnard's Star. At a distance of less than two parsecs (5.9 light-years, to be exact), this small red M-type dwarf has an apparent motion that is comparatively easy to measure. In a span of nine decades, its observable change in position is roughly equal to half the apparent diameter of the Full Moon. This led van de Kamp to try to observe the position of Barnard's Star over several decades with a higher level of accuracy than had ever been attempted. The idea was to construct a "flight path" for the object, for any deviations from a perfectly straight path could be interpreted as the gravitational fingerprint of a large planetary companion. To do this, he took and measured thousands of photographic plates to search for tiny "wobbles" in the star's path. Such wobbles did in fact show up, and in 1963 van de Kamp concluded that Barnard's Star was accompanied by one Jupiter-sized planet in an eccentric 24-year orbit. Six years later, he reinterpreted the data and suggested that two jovian planets revolved around the star in circular orbits: one having an orbital period of 12 years, the other, 24 years.

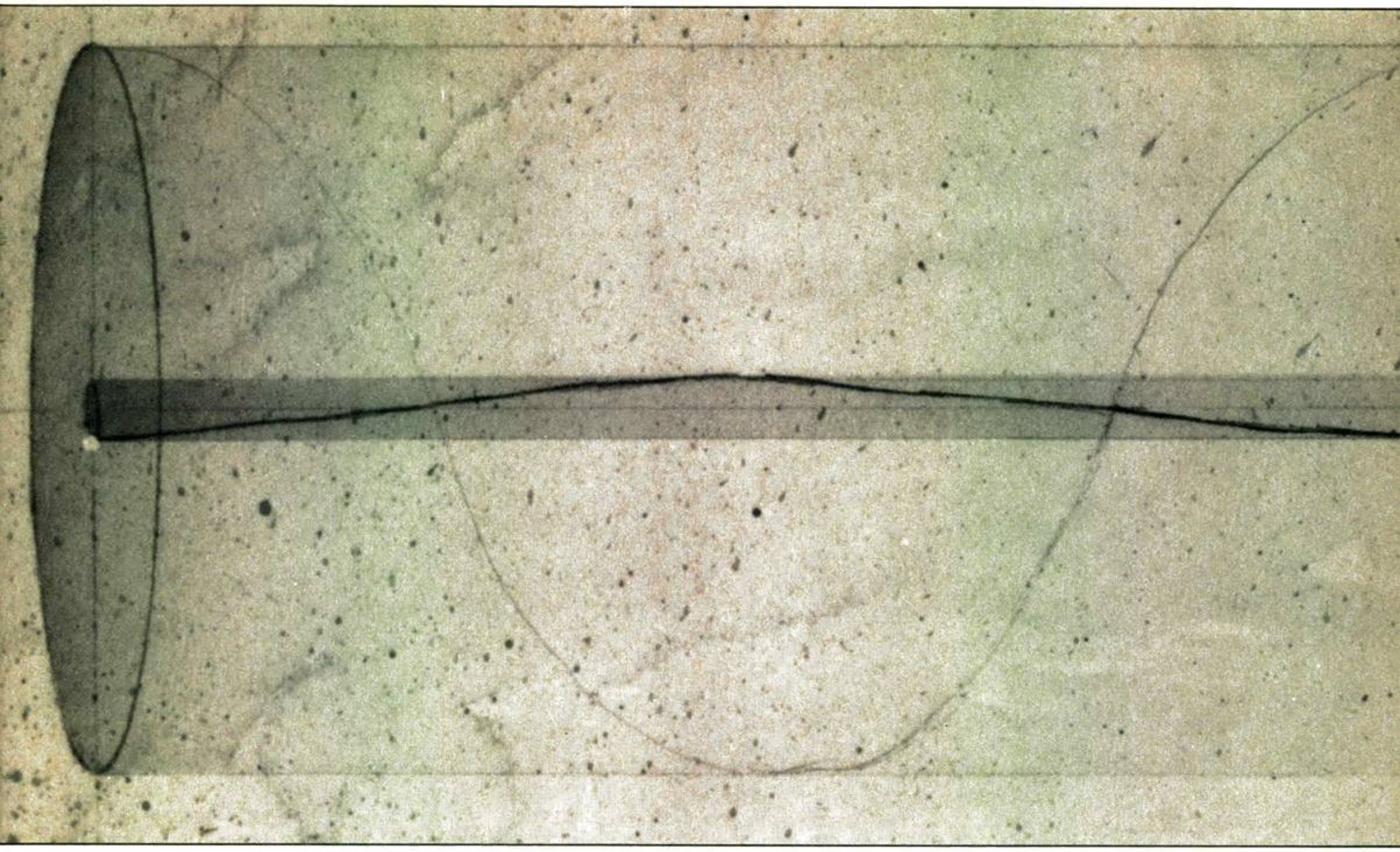
In the early 1970s, van de Kamp's conclusions were challenged. The critical 1949 and 1957 observations coincided with periods during which adjustments and alterations were made on the Sproul telescope. Further, *In order to detect the gravitational effects of an Earth-mass planet, astronomers must measure the position of a star to less than a billionth of a degree.*


A star without planets moves across the sky in a straight line.
A star with planets has slight "wobbles" superimposed on its straight-line motion.

### Estimated Perturbations of Some Nearby Stars Due to a Jupiter Mass Planet in a Jupiter-like Orbit

| | Star's Mass (Sun =1) | Distance (light-years) | Planet's Orbital Period (years) | Perturbation of Star's Path (seconds of arc) |
|---|---|---|---|---|
| **Proxima Centauri (Alpha Cen. C)** | 0.12 | 4.3 | 34 | 0.032 |
| **Alpha Cen. A** | 1.00 | 4.4 | 12 | 0.004 |
| **Alpha Cen. B** | 0.81 | 4.4 | 13 | 0.005 |
| **Barnard's Star** | 0.16 | 6.0 | 30 | 0.0017 |
| **Sirius A** | 1.58 | 8.7 | 9 | 0.001 |
| **Sirius B** | 0.26 | 8.9 | 24 | 0.007 |

**Although current ground-based astrometric studies *could* detect a world of Jupiter's mass orbiting some of the nearby stars, none have yet been found. While these techniques allow us to put some limits on the types of planets orbiting the nearest few stars, they do not let us reach out far enough to search a statistically meaningful number of stars.**



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In the early 1970s, van de Kamp's conclusions were challenged. The critical 1949 and 1957 observations coincided with periods during which adjustments and alterations were made on the Sproul telescope. Further, the precise optical characteristics of the 24-inch refractor may have been inadequately modeled, allowing small errors to creep into the data unnoticed. The debate has quieted in recent years, but Robert Harrington and his colleagues at the United States Naval Observatory (USNO) in Flagstaff, Arizona, seem finally to have put the issue to rest. After careful measurements of their own plates taken with the USNO 1.5 meter (61-inch) astrometric reflector, the investigators concluded that Barnard's Star has no detectable wobble in its motion across the sky. At the level of accuracy obtained, this rules out Jupiter-like companions; it does not, however, preclude smaller bodies. At this moment, we have no unequivocal evidence for the existence of planets beyond those that orbit our Sun.

Present ideas about the formation of planetary systems suggest that planets should be plentiful, since no highly improbable events seem necessary to account for their existence around single stars such as the Sun or Barnard's Star. But can we say the same about the 50 to 70 percent of all stars in the Galaxy that belong to multiple systems? A computer model published by Harrington in 1977 outlined the conditions under which stable orbits, consistent with planetary formation, could occur. In theory, the most stable orbits should occur in systems where the members of the binary are either very close together or very far apart. A pair of very close stars will produce a gravitational field differing only slightly from that of a single star. For a well-separated binary, each component will have a large volume of space over which

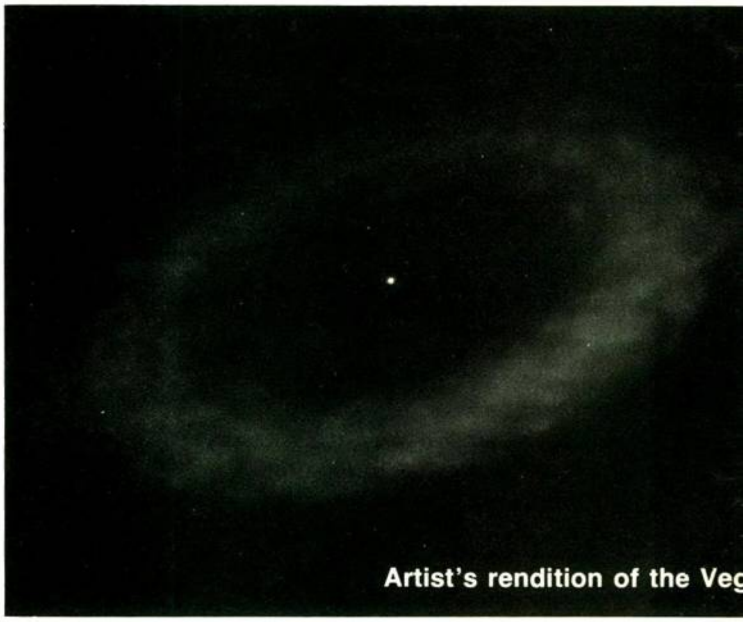
*Knowledge of even one extrasolar planet comparable to Earth would help legitimize NASA's Search for Extraterrestrial Intelligence, which many now view as an exotic gamble.*

it has gravitational sovereignty. Harrington's work suggested that stable orbits will be possible in systems where "distance ratios" are greater than four to one — that is, planets can form if they lie at least four times farther from a close binary than the stars are from each other, or if the stars of the binary are separated by at least four radii of a planet's orbit. Although the gravitational confusion in systems of three or more stars is even greater, safe planetary orbits in such systems are nevertheless possible. (See "The Three Suns of Centaurus," ASTRONOMY, January 1982.) In spite of the peculiarities of binaries and multiples, their statistical importance is too great for any study of extrasolar planets to overlook them.

In a galaxy of hundreds of billions of stars, planetary systems should be numerous and varied, but the gap between "what should be" and "what we know of" could scarcely be broader in any field of astronomy than it is in studies of the detection of extrasolar planets. The IRAS discovery of particle clouds around Vega and Fomalhaut is, so far, the closest thing to evidence of planetary systems outside our own, but Pluto still remains the most distant world we know. Van de Kamp's painstaking labors over three decades exemplify the importance many astronomers associate with the problem. Observatories such as the USNO have begun improved programs, but they are still largely developmental, not true surveys. Astronomers need statistical information on many stars, not merely the chance detection of a single planet around one of the Sun's close neighbors.

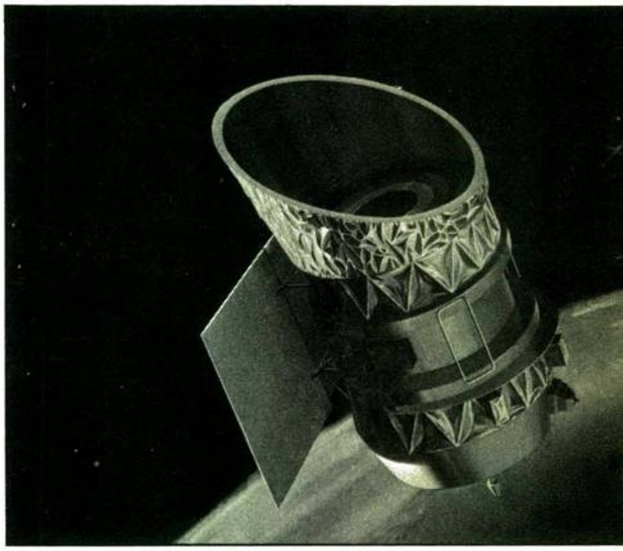
Conducting a survey of a statistically significant number of stars lying within a radius of 12 parsecs (about 39 light-years) of the Sun is currently considered a reasonable goal. As these nearby stars move through space, they exhibit greater angular movement over a given period of time than more distant stars. The most distant stars appear motionless, making them valuable as a frame of reference. Thus astronomers can use positional astronomy — *astrometry* — to detect motions of nearby stars with respect to distant background objects.

Measuring the position of a nearby star may seem reasonably straightforward, but it requires a phenomenal degree of accuracy. In order to detect the gravitational effects of a planet of roughly the Earth's mass, measurements must approach the microarcsecond level — a resolution of less than one billionth of a degree. Here's a way to appreciate this kind of accuracy. The



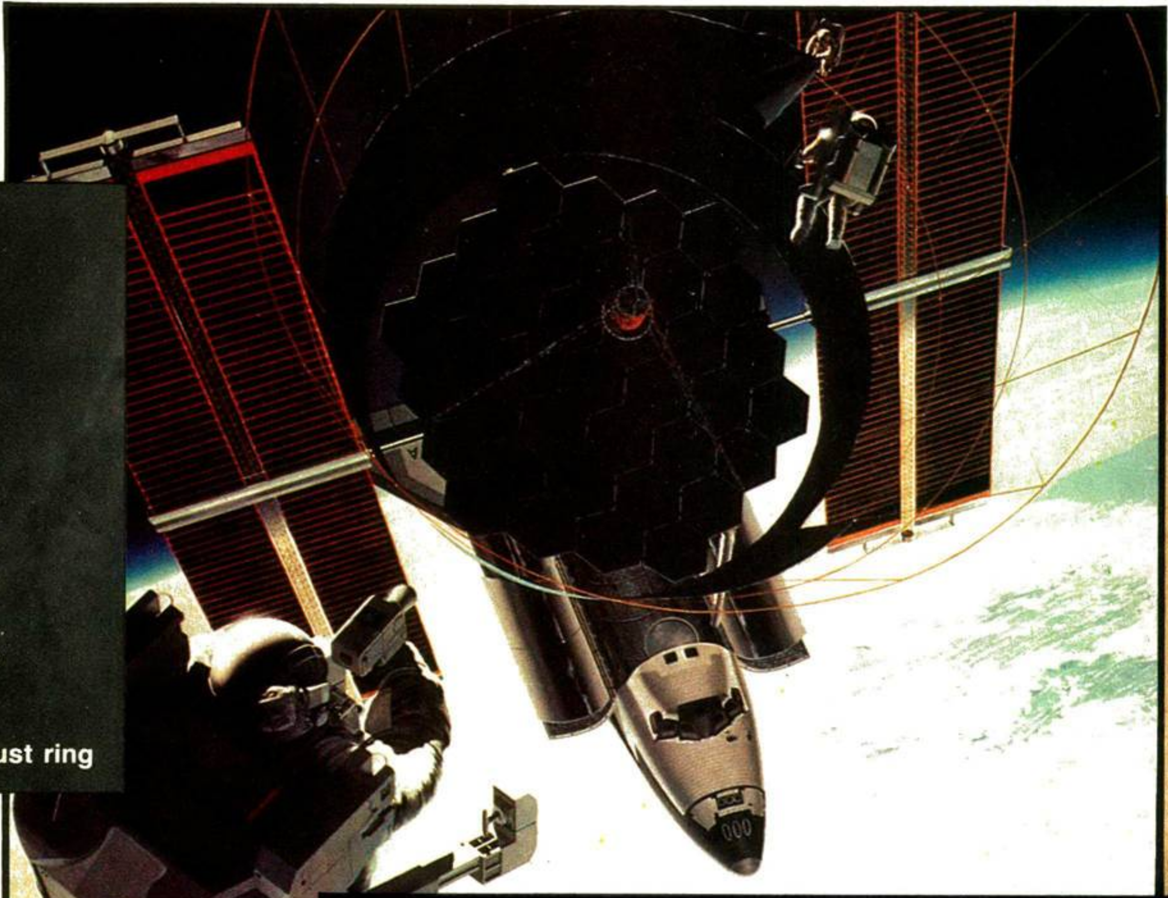
**Artist's rendition of the Veg**

**In its year of operation, the Infrared Astronomical Satellite (IRAS) detected dusty rings around some 50 stars. The first, discovered around the star Vega, may contain up to 300 Earth masses of material. But a similar craft in orbit about Vega could not observe our solar system — the emission from the planets would be too weak to detect close to the Sun's overwhelming glare.**



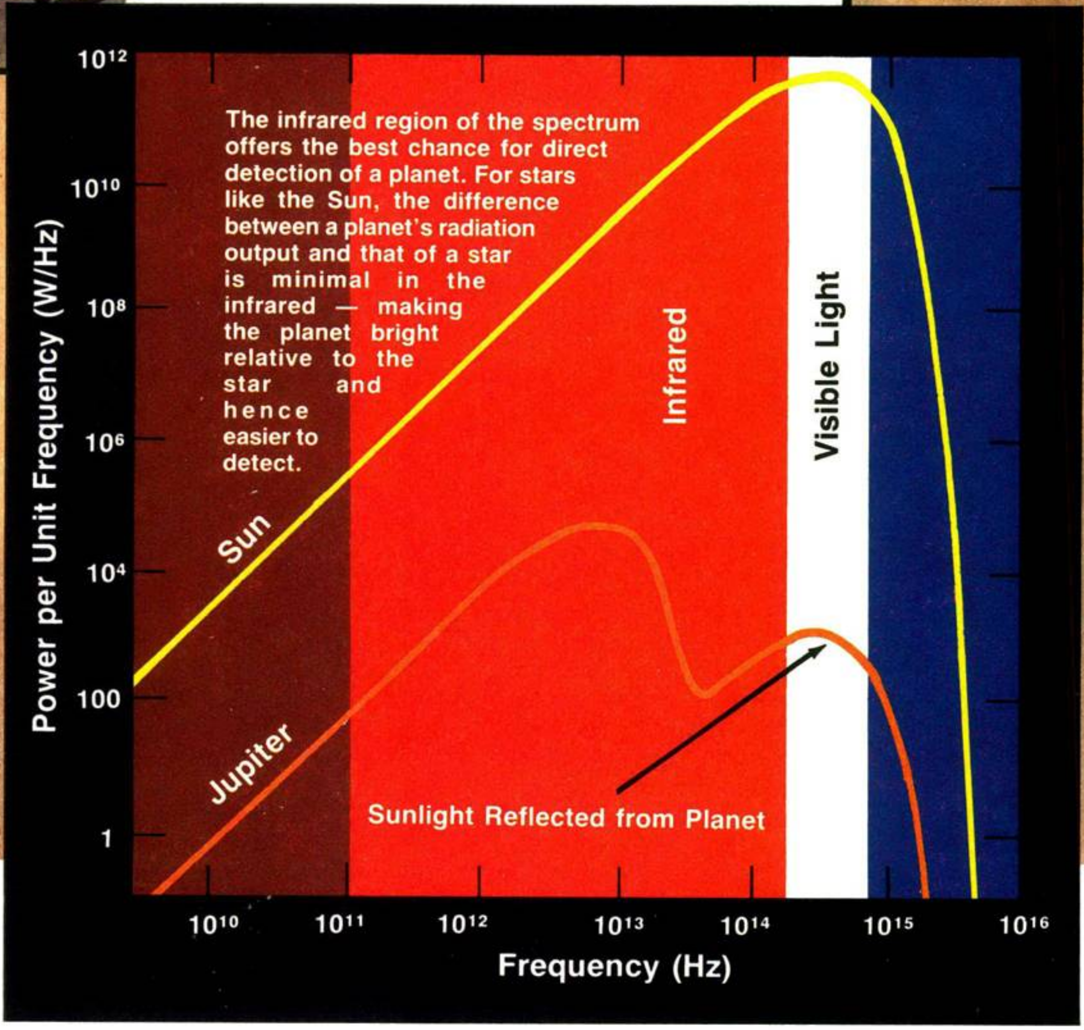
**The Infrared Astronomical Satellite**

NASA art by Paul Hudson

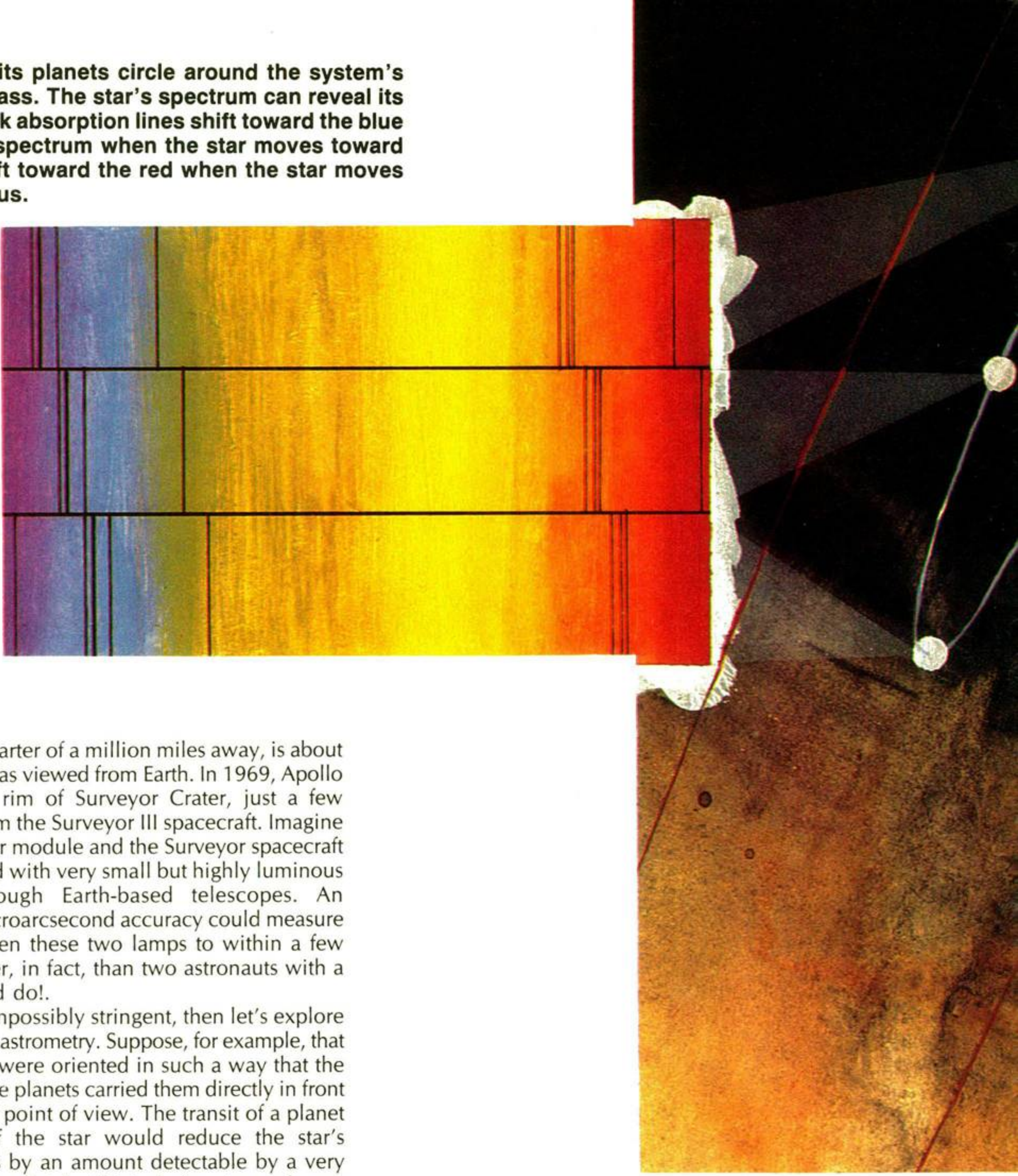


The proposed 15 to 30-meter Large Deployable Reflector would have a much higher angular resolution than IRAS, but it could not study enough stars to perform a statistically meaningful survey.

dust ring



The infrared region of the spectrum offers the best chance for direct detection of a planet. For stars like the Sun, the difference between a planet's radiation output and that of a star is minimal in the infrared — making the planet bright relative to the star and hence easier to detect.



**A star and its planets circle around the system's center of mass. The star's spectrum can reveal its motion. Dark absorption lines shift toward the blue end of the spectrum when the star moves toward us, and shift toward the red when the star moves away from us.**

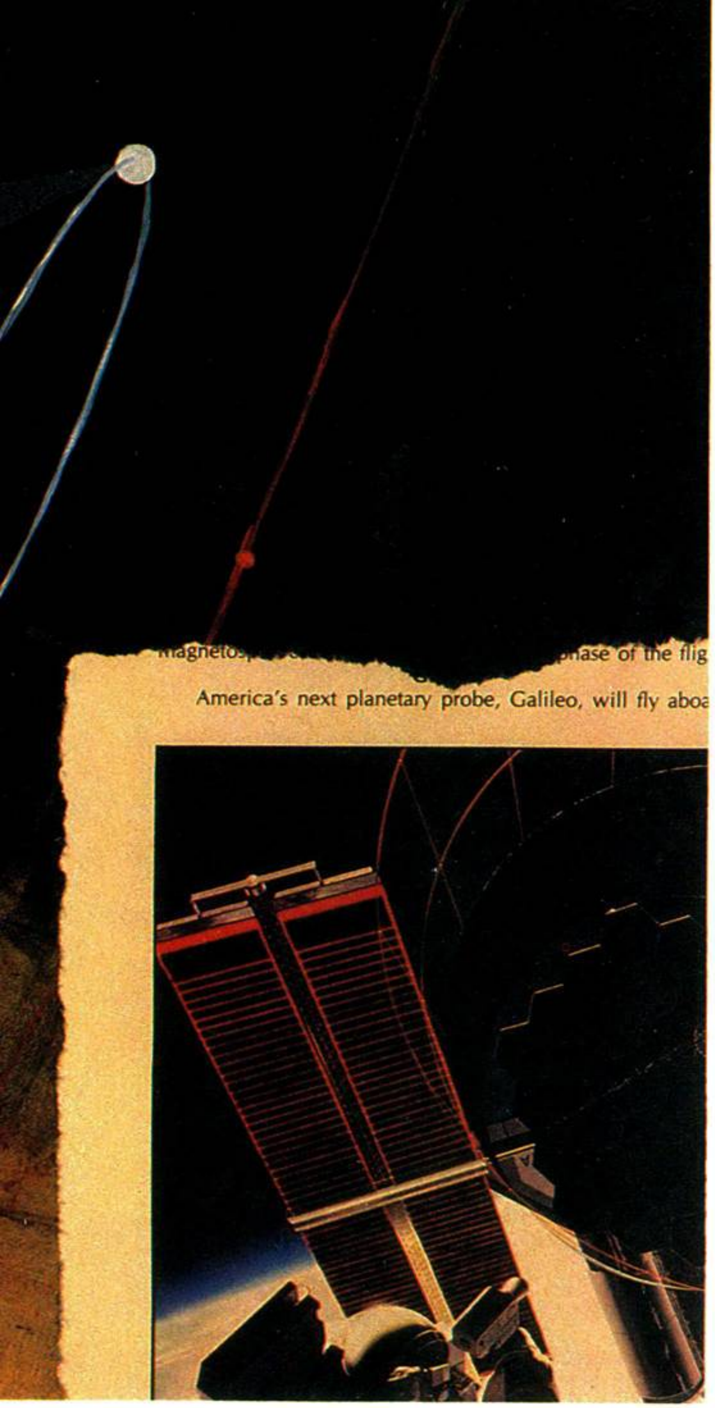
Moon, roughly a quarter of a million miles away, is about half a degree across as viewed from Earth. In 1969, Apollo 12 landed on the rim of Surveyor Crater, just a few hundred meters from the Surveyor III spacecraft. Imagine that the Apollo lunar module and the Surveyor spacecraft were both equipped with very small but highly luminous lights visible through Earth-based telescopes. An instrument with microarcsecond accuracy could measure the distance between these two lamps to within a few millimeters — better, in fact, than two astronauts with a tape measure could do!.

If this sounds impossibly stringent, then let's explore some alternatives to astrometry. Suppose, for example, that a planetary system were oriented in such a way that the orbits of one or more planets carried them directly in front of the star from our point of view. The transit of a planet across the face of the star would reduce the star's brightness, perhaps by an amount detectable by a very sensitive photometer. But for this technique to work, you need both patience and luck in abundant quantities.

Photons reflected from the surfaces of distant planets are probably reaching Earth at this very moment. We are unable to identify them as such because they are hard to separate from those emitted by the far more brilliant parent star. If it were possible to block the light of the star, then the planets might be visible. But this concept, which seems attractively simple at first, becomes rather difficult in practice, and is unlikely to be realized for some time.

A more feasible way of directly imaging an extrasolar planet would be to observe in infrared wavelengths, since planets put out most of their energy in these wavelengths. The "brightness ratio" between the star and the planet would be much smaller in infrared than in visible light. The IRAS satellite, while highly sensitive to extremely low infrared emissions, is somewhat near-sighted — its instruments cannot clearly see very small pieces of the sky. Put another way, IRAS doesn't have the angular resolution necessary for resolving planets. NASA is considering another infrared satellite, called the Large Deployable Reflector, that would have a much higher resolution than IRAS. It appears, however, that the 15 to 30-meter instrument currently envisioned would be useful for stars only within about three parsecs — not enough to constitute a truly meaningful survey.

There is only one major technique not based on positional information, and therefore not necessarily restricted to nearby stars: radial velocity spectrometry. The gravitational tug of a star's attendant planets can be observed in the star's spectrum. Both star and planets orbit around the system's common center of mass. As the star moves toward us, dark absorption lines in its rainbow-like spectrum shift toward the blue end of the spectrum; as the star moves away from us, the lines shift toward the red end. By examining the blueshift or redshift of a stellar spectrum, astronomers can measure the star's radial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America's next planetary probe, Galileo, will fly abo

*In a Galaxy of hundreds of billions of stars, planetary systems should be numerous — but the gap between "should be" and "what we know of" could scarcely be broader in any field of astronomy than it is in studies of the worlds beyond our Sun.*

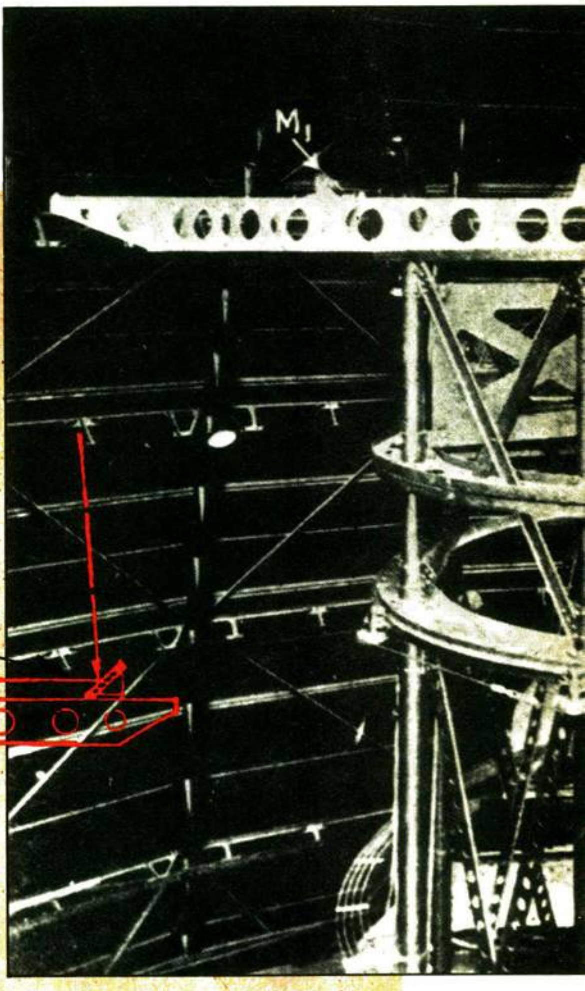
velocity — the rate at which it moves toward us or away from us — to an accuracy of about one kilometer per second. But this isn't good enough to detect planets. Astronomers need accuracies in the range of 10 to 20 *meters* per second to find planets with this method. Recent work at the University of Arizona's Steward Observatory, using a 1.5-meter telescope, has shown promise for attaining an accuracy of 15 meters per second — enough to detect jovian planets orbiting stars of fifth magnitude or brighter. Some astronomers believe that ground-based systems may eventually reach accuracies approaching one meter per second. Radial velocity spectrometry, unlike astrometry, suffers little from the effects of the Earth's atmosphere; this makes satellite observatories unnecessary — an important cost advantage. The only important difficulty with the radial velocity technique stems from the possibility that target stars may undergo intrinsic radial velocity changes independent of those that might be induced by planets — through regular pulsations, for example. If these shifts were to occur at the level of 10 to 20 meters per second, and particularly if they were periodic in nature, they could be misinterpreted as being caused by planetary companions. If the Sun undergoes such changes, observing and understanding them would greatly reduce the risk of misinterpreting planetary detection data derived from studying a star's spectrum.

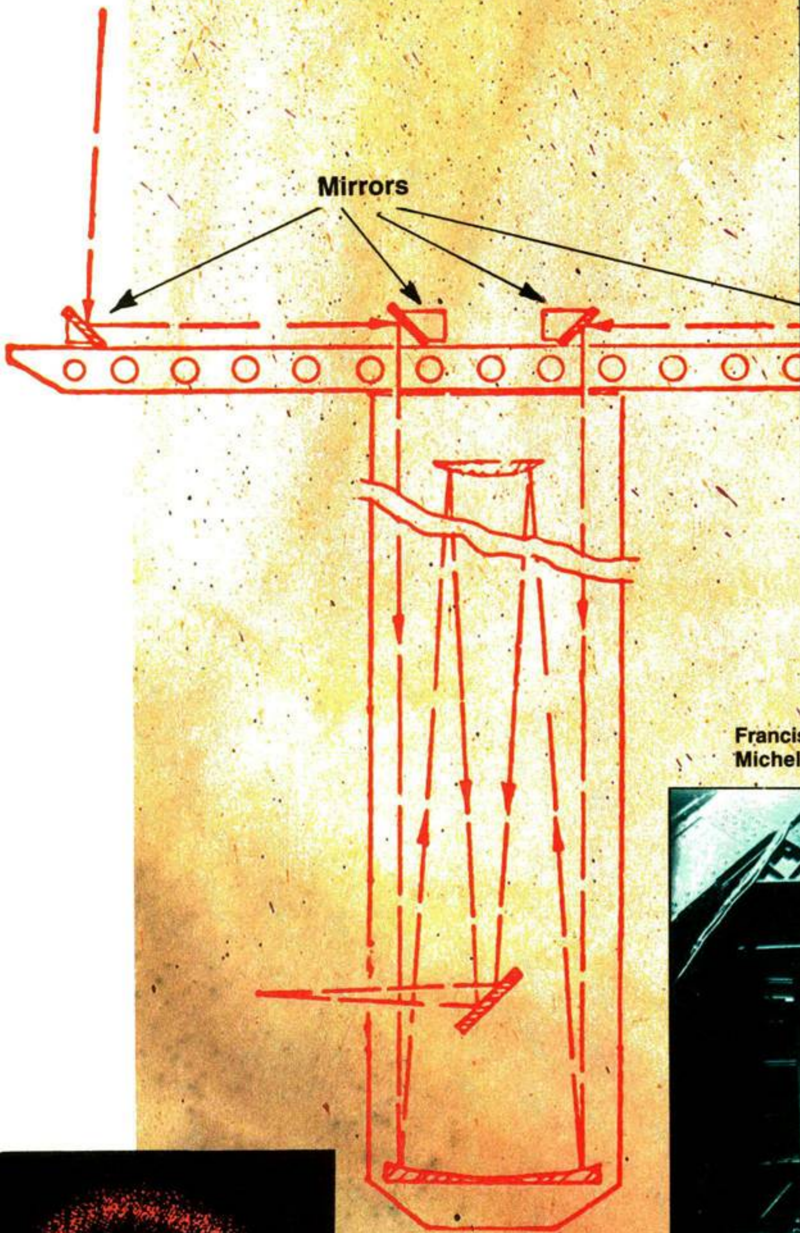
Perhaps the most complex, technologically demanding, and potentially accurate methods of planetary detection are those involving interferometry. These techniques capitalize on the way light waves interfere with one another, producing alternating bright and dark bands where the waves add together and cancel each other, respectively. The ground-based systems currently under development have as their ultimate objective the elimination of all error due to atmospheric turbulence. Planners envision systems with accuracies in the 10 to 100 microarcsecond range, with still greater potential for satellite instruments.

Stellar interferometry was first demonstrated by Albert Michelson in 1920, but it was given little attention until the 1960s. Today, three distinct approaches are under study: two-aperture, amplitude, and speckle interferometry. Two-aperture interferometry, as the name implies, requires two separate telescopes observing the same target. Astronomers can determine the exact position of the target by comparing the images from the two telescopes. Amplitude and speckle interferometry are simpler and less expensive, and are the only techniques well-suited to observing binaries. They have already been used to measure stellar diameters and the separation of binaries, and even to produce an "image" of the surface of the nearby supergiant variable star Betelgeuse.

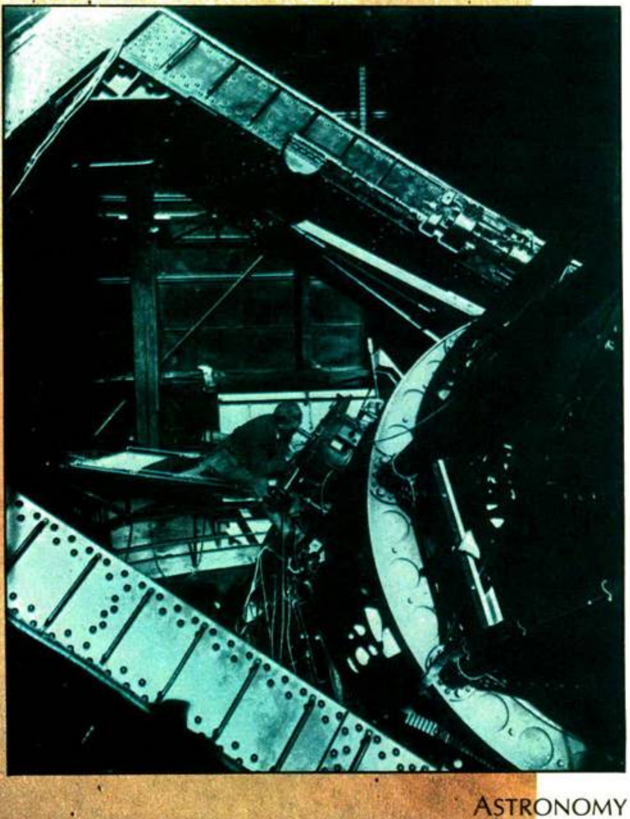
Probably the most ambitious of any of the planetary detection research programs now under way is Michael Shao's two-aperture interferometry work at the Massachusetts Institute of Technology. Shao uses incredibly precise optical systems to bring the signals from their respective telescopes to the interferometer. Increasing the distance between the two telescopes produces a corresponding increase in astrometric accuracy, but also magnifies the problems involved in getting the signals to the interferometer. A significant breakthrough appears necessary in order for these long-baseline systems to live

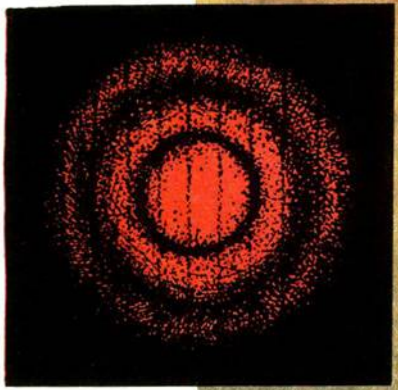
**Using a technique similar to Michelson's, astronomers can obtain very accurate stellar positions. Current systems require an interferometer up to twice as long as Michelson's. At least two stars must appear in the telescope's field; when combined, the light of these stars creates an interference pattern. Centering the field first on one star then on the other changes the pattern, giving astronomers the separation between the stars.**



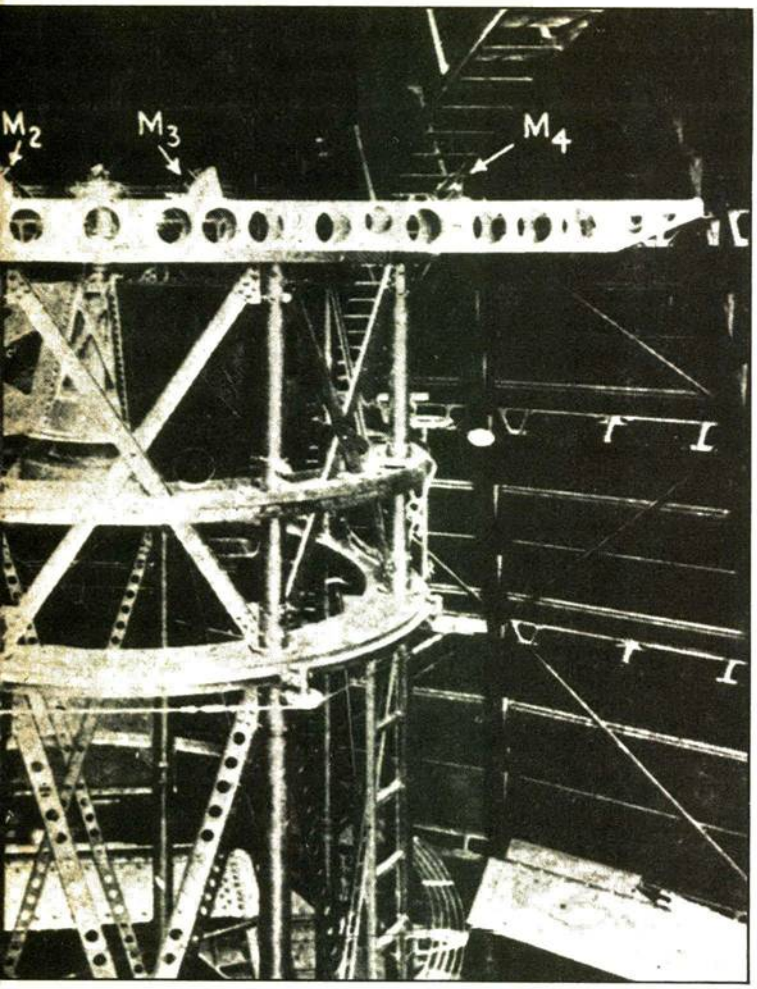


**Francis Pease studies an image produced by the Michelson interferometer.**





**Interference Pattern (vertical lines) of Star Betelgeuse**



Mount Wilson Observatory photos courtesy AIP Niels Bohr Library

*For those developing ground-based detectors, the ultimate objective is the elimination of error due to Earth's turbulent atmosphere.*

**The Michelson interferometer as attached to Mount Wilson Observatory's 100-inch reflector. In 1920, this pairing allowed Albert Michelson and Francis Pease to determine the diameter of the giant star Betelgeuse in Orion. Their result: 0.47 second of arc, or 250 million miles. This star pulsates irregularly, and modern values for its diameter range from 350 million to 500 million miles.**

up to their very considerable potential.

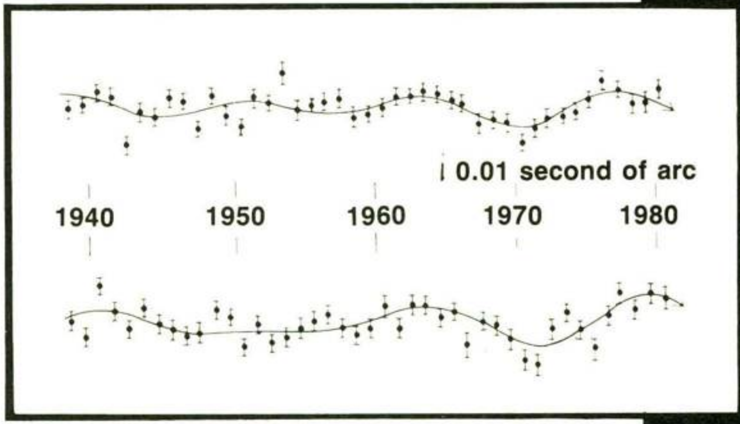
Meanwhile, at the University of Maryland, Douglas Currie is developing an amplitude interferometer designed to measure the distances between stars of binary systems. In a sense, amplitude interferometry is a two-aperture technique — a single telescope combines the light from two stars, producing an interference pattern of alternating light and dark bands. As the telescope is centered on each star in the field, the pattern's spacing and orientation change slightly. These changes give astronomers a means of accurately determining the relative positions of the system's components. Planets would reveal themselves through periodic small wobbles in the orbit of their parent star. This method has the obvious advantage of being able to use existing telescopes. But in order to work, both apertures must image both components of the binary through the same column of turbulent air. The stars must not be separated by more than a certain angle — called the *isoplanatic* angle — which depends both on atmospheric conditions and instrument characteristics. Binaries separated by several arcseconds may in many cases be too far apart for useful observations.

Speckle interferometry, which is also limited by the isoplanatic angle and is thus restricted to close binary stars, has an important advantage over the other techniques — it's a lot simpler to do. In a long-exposure photograph of a star, our turbulent atmosphere causes the star's position to randomly change by a small amount, blurring the picture. But in speckle interferometry, an extremely rapid shutter "freezes" the randomly moving star image onto a photographic plate, recording the individual "speckles" that make up the total star image. Since each of these ultrashort exposures is just a few milliseconds long, atmospheric turbulence doesn't have time to blur the speckles together. In less than a second of total exposure time, astronomers can make up to 100 speckle images. In the case of a binary star, each of the system's components produces a speckle. Each frame in this photo series is then combined to produce a composite pattern, complete with light and dark interference bands whose spacing and position carry information about the binary's component stars. Planets might reveal themselves through changes in a binary's interference pattern. With few technological complexities and potential accuracies better than 100 microarcseconds, speckle interferometry is understandably one of the most popular planetary detection techniques currently under development.

The unifying force between these research programs is NASA. Upon its creation over 25 years ago, one of NASA's fundamental priorities was improving our understanding of the formation of the solar system. Observes David Black of NASA's Ames Research Center in Mountain View, California, "If you look into planetary detection programs, all roads will lead you back here." In the late 1970s, he co-chaired a NASA-sponsored summer workshop designed to take the first serious look at truly high-technology planetary detection. Called Project Orion, the study examined some of the most basic issues of planetary detection in order to assess the feasibility of an advanced interferometer. While the Orion system was found to be too complex and expensive to build, the workshops proved to be a springboard for planetary detection research. Black is still responsible for NASA's support of research in this area, and while technological progress has been steady, he has seen a peculiar problem emerge. NASA is studying a design for an orbital telescope — called the Astrometric Telescope — with the capability to perform the first major planetary detection survey, but the system is also considered a powerful tool for astrophysics research. Black, himself a theoretical astrophysicist, finds that the new project "falls in a crack." When the question of who should pay for the satellite arises, the planetary scientists point to the astrophysicists, and vice versa. What is now a political dilemma, however, may become a blessing later on. The

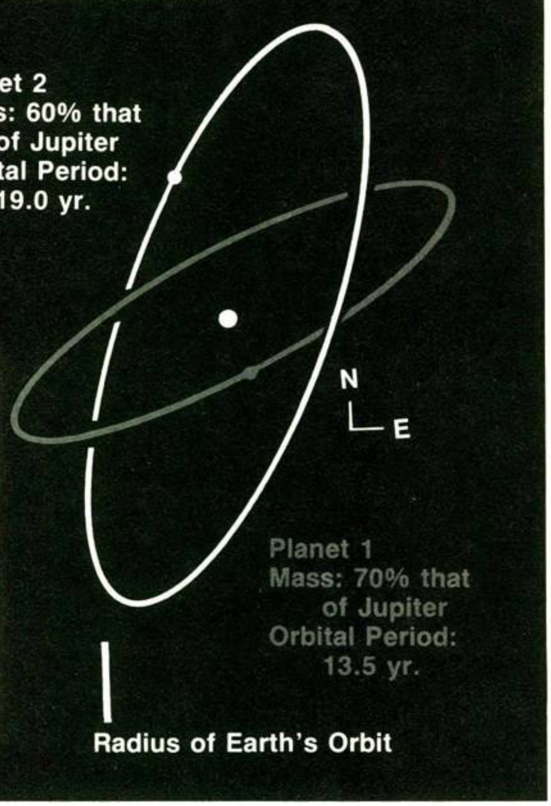
*There is currently no unequivocal observational evidence for the existence of other planetary systems.*

**The calculated perturbations of the motion of Barnard's Star from 1938 to 1980. The top curve shows the star's orbital displacement in right ascension, and the bottom curve shows its displacement in declination.**



Diagrams adapted from Peter van de Kamp's *Stellar Paths.*

**Calculated apparent orbits of the two planets supposedly responsible for the "wobbles" in the motion of Barnard's Star.**



telescope's many applications make it extremely cost-effective, increasing its chances of making it into the tight NASA budget.

The Astrometric Telescope concept was originated by George Gatewood at the Allegheny Observatory in Pittsburgh, as a spin-off from his work on a ground-based Multichannel Astrometric Photometer (MAP). In only 15 minutes of observing time, Gatewood's MAP can yield star positions accurate to 5000 microarcseconds. This, combined with its simple design, made Gatewood's system a prime candidate for an orbital astrometric instrument. The Lockheed Corporation's Palo Alto Research Laboratory was asked to report to NASA Ames on the feasibility of adapting a MAP-like system to a Shuttle-launched satellite. An interferometer system, based on the work of Shao at M.I.T., was also to be given consideration. Previously, in a 1979 study, Lockheed had done a similar comparison of an imaging telescope and an interferometer. Both were direct detection instruments designed to image planets, and neither turned out to be a strong candidate for future development. But when Lockheed released its 1982 report on astrometric instruments, the imaging system based on Gatewood's MAP came away looking very much like a winner.

The telescope operates by interrupting the light of the stars in its view, using a device called a Ronchi ruling. A ruling is a transparent "carrier" crossed with very accurately spaced opaque lines. The ruling moves back and forth across the image plane of the telescope, causing each star's brightness to vary in a predictable way. The brightness of any two stars at any given moment will be dependent upon the position of the ruling at that moment. By knowing the precise spacing of the ruling lines and the speed of their motion, astronomers can determine the stars' relative positions in the axis of motion of the ruling. Lothar Bandermann, who headed the Lockheed study, describes the technology behind the Astrometric Telescope as "state of the art, or possibly better." He believes that an instrument could conceivably be placed in orbit by the end of this decade.

A fully developed orbiting Astrometric Telescope would achieve the microarcsecond accuracy needed for planetary detection. The only other space-based systems capable of astrometry are the Space Telescope, scheduled for launch in August 1986, and the European Space Agency's proposed Hipparchos satellite. The Space Telescope will be accurate to only about 2000 microarcseconds, an accuracy comparable to current ground-based instruments. Hipparchos, an astrometric survey instrument presently in design stages, is unlikely to greatly exceed an accuracy of 1000 microarcseconds. The Astrometric Telescope, a much less expensive project than the Space Telescope, would use "off the shelf" hardware and would be built around an existing 1-meter diameter spacecraft design. Its baseline task would be the detection of an Earth-mass planet in a five-year orbit around a star within 10 parsecs of Earth, but many other kinds of studies are possible. Precise measurements of Pluto's motion, for example, could reveal a tenth planet in our solar system, and observations of some binary star systems may yield information on such interesting non-planetary companions as black holes. The Astrometric Telescope is undeniably a very worthy competitor for a slice of NASA's funding pie.

Today, relative star positions are known to accuracies typically better than an arcsecond. These positions are

Watching the Sun from the distance of Barnard's Star (about 6 light-years), an observer would notice a small periodic deflection of its motion across the sky. Due to the gravitational effects of the solar system's planets, our Sun would undergo a maximum shift of 5600 microarcseconds. Our hypothetical observer would have at least as much difficulty detecting the presence of our planets as terrestrial astronomers have had with planets around Barnard's Star!

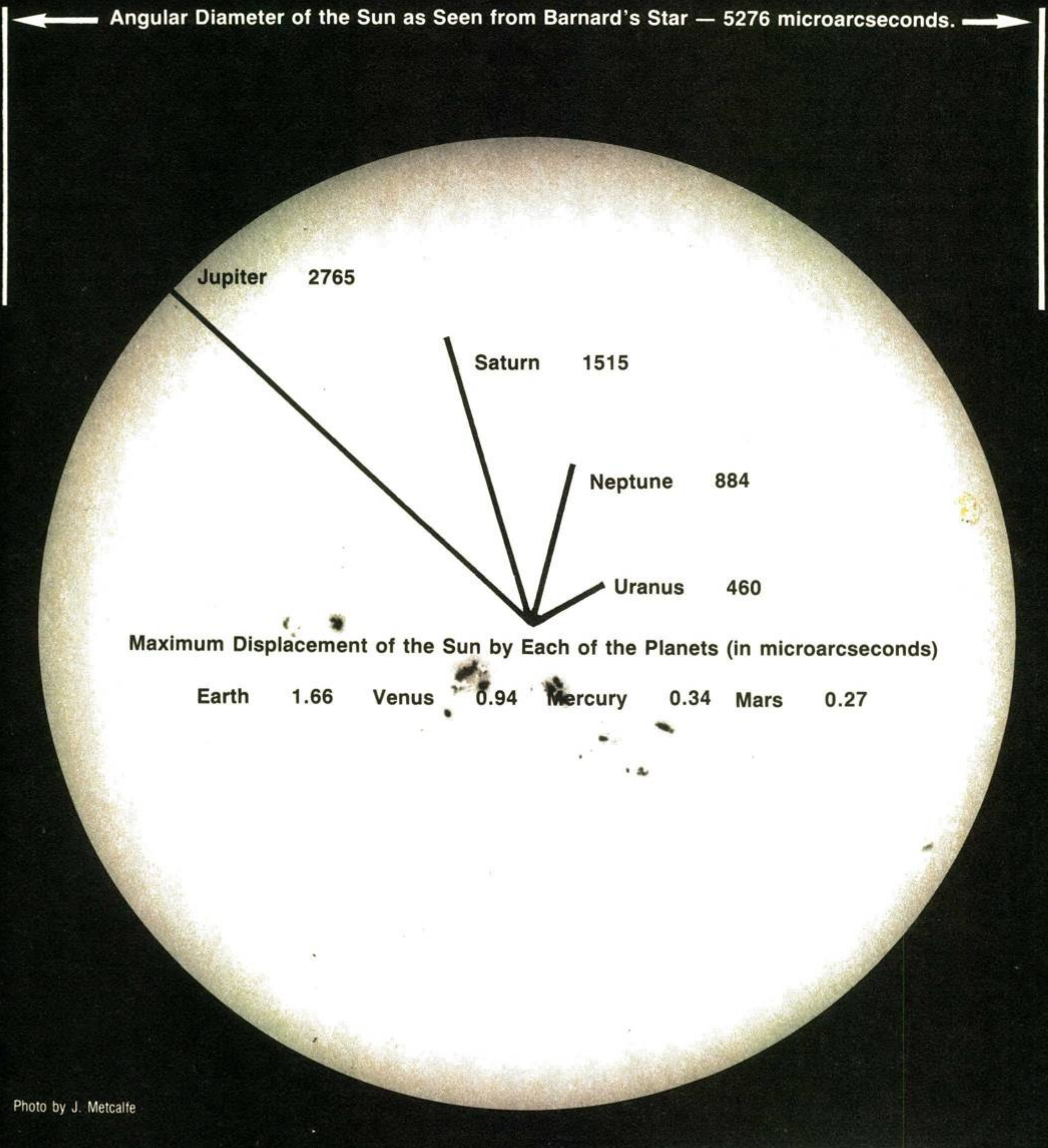
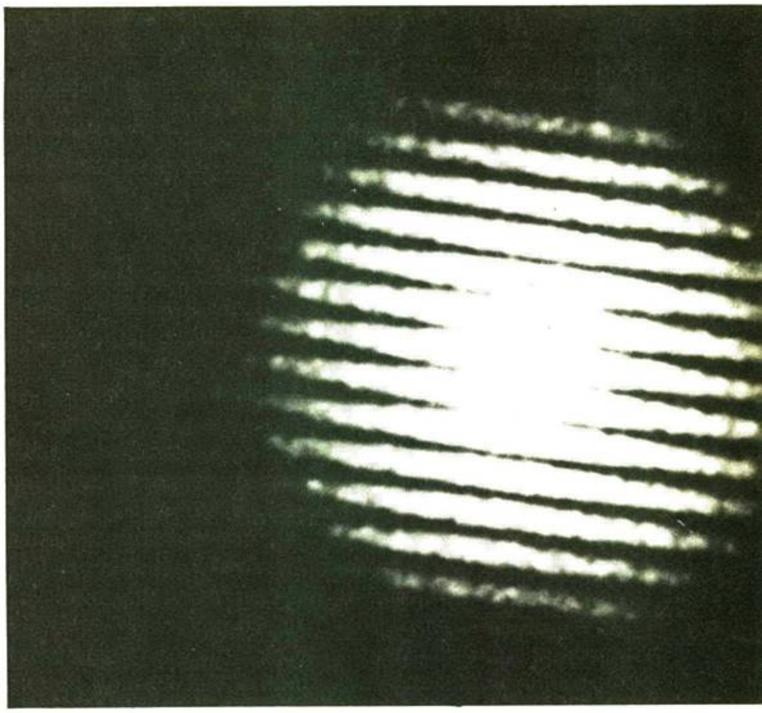


Photo by J. Metcalfe

*It will take up to 15 years from the initiation of a space-based program until firm data are available. "Until that data is in hand," says Black, "we have no way of knowing whether our entire scientific effort to understand the origin of the solar system is addressing the right questions."*


NOAO/Kitt Peak

constantly changing, however, and in order to do astrometric observations at the microarsecond level, astronomers must define a reference frame of stars at a similar accuracy. The time required to determine the position of a star is referred to as the integration time, and it depends on the star's apparent luminosity. The limitations of a photodetector's sensitivity may render very distant and motionless, but comparatively dim stars useless for reference purposes. The Lockheed researchers anticipate that for a 20th magnitude star, 10 microarcsecond accuracy would require 360 hours of observing! Even if such extended integration times were practical, they would undoubtedly contain systematic errors.

Shorter integration times would work for nearer and brighter stars, but their positional changes — over the five-year survey period proposed — could seriously degrade the quality of the reference frame. Bright, distant quasars would be ideal reference points, combining short integration times and long-term positional stability. Unfortunately, the odds of finding a quasar in any given field in the telescope's small (10-arcminute) field of view are currently about a thousand to one, although this situation will improve as more of these objects are discovered. Clearly, there is an important trade-off between speed of integration and the stability of the stellar reference frame. Nevertheless, Lockheed's results indicate that a microarcsecond reference frame should have an integration time somewhere between one and ten hours. Highly sensitive detectors are vital since their total efficiency is cut down by the half-opaque Ronchi ruling.

And what of the ruling itself? It will most likely be fused silica to minimize thermal expansion, and measure 50 cm long and 2.5 cm wide. Diamond ruling or photolithography will draw the opaque rules — about 50 per millimeter. Since the ruling modulates all stars in the field of view *simultaneously*, sources of error independent of the field, such as telescope vibration and thermal expansion, are canceled out of the relative star position data. A magnetic field will suspend the ruling between a set of rails, and the ruling will be moved by an electric current. The forces necessary to keep the ruling structure suspended will be very small in the "zero-gravity" environment of Earth orbit. Since there is no physical contact with the main telescope structure, this design greatly decreases any vibrations that might reach the ruling.

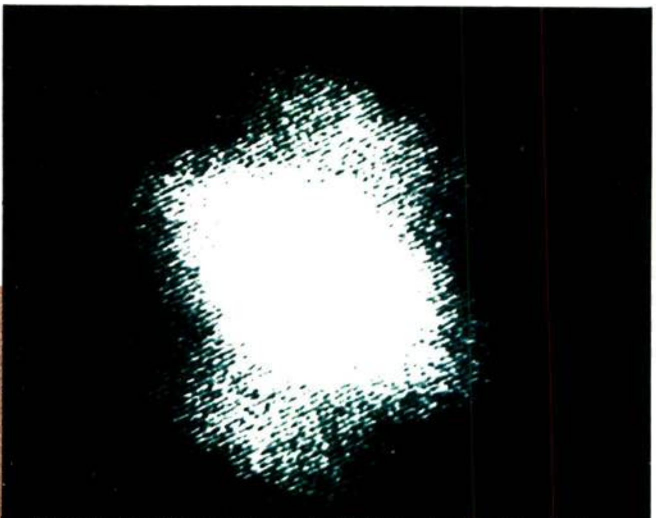
The ruling is located at the telescope's prime focus. The 1-meter primary mirror will be housed in an 8-meter-long barrel made of graphite-epoxy, or perhaps an even more exotic material. Depending on the thermal expansion properties of the barrel's material, a self-compensating steel-aluminum truss may be used as a precaution against changes in the barrel's length. Other telescope structures will be thermally protected using insulation, heaters, and radiators.

For an elongated instrument like the Astrometric Telescope, the spacecraft's attitude control system has a difficult task to perform. To compensate for on-orbit torques, which could cause the field of view to drift off the target stars in about a minute, the telescope must be guided constantly. Vibrations caused by the motion of the Ronchi ruling, the sloshing of propellants, and station-keeping will also have to be controlled. These create no shortage of engineering challenges, but no great leaps beyond state-of-the art technologies will be required.

There is little doubt that the project's major challenge will be in the area of data reduction, in squeezing information out of the craft's raw signals. How can a star's perturbed path be "unravelled" to separate large planets from small ones, or reveal orbit size and eccentricity? Before any intrinsic perturbations can be recognized, astronomers must account for a number of extraneous effects. The Earth's gravity, for example, will bend incoming starlight in an amount that depends on the orientation of Earth and satellite in relation to the direction of observation. The effect on relative star positions is small but with such high-accuracy goals it can't be ignored.

Under normal circumstances, a satellite in Earth orbit is not considered to have a velocity that is very significant in terms of the speed of light. An astronaut aboard the Space Shuttle does not see any relativistic effects, but with considerably better vision he *would observe something* very strange. Looking at the Pleiades star cluster, just after it had risen above the Earth's horizon, the stars would appear closer together than they would if he were not

Astronomers combined 50 speckle photographs to produce this composite interference pattern of the binary star Kappa Ursae Majoris. The spacing between fringes implies an angular separation of 0.272 second of arc between the system's components. The orientation of the fringes reveals the position of this star's close companion.



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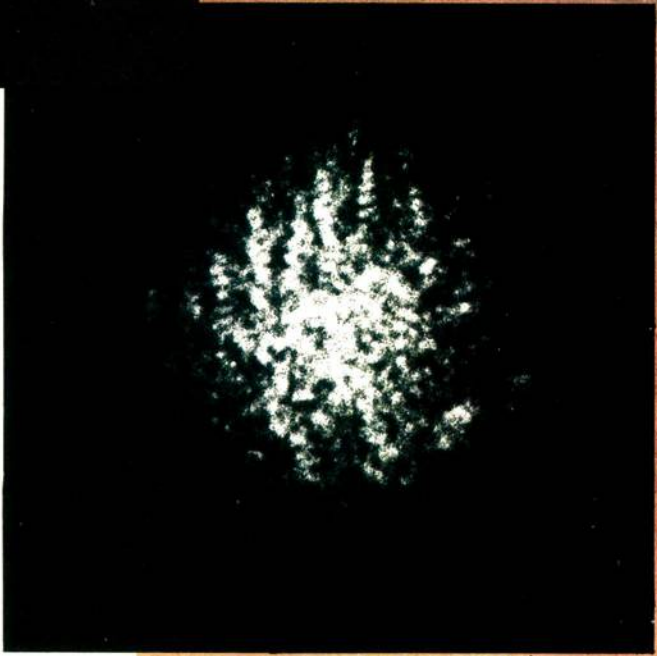
Speckle interferometry shows that the star Eta Orionis has two companions. The primary and secondary stars of the system, which are separated by more than a second of arc, produce nearly 100 very fine fringes. But a third previously unresolved companion creates the three broad fringes. This star was only 44 milliarcseconds from the system's primary when this observation was made.



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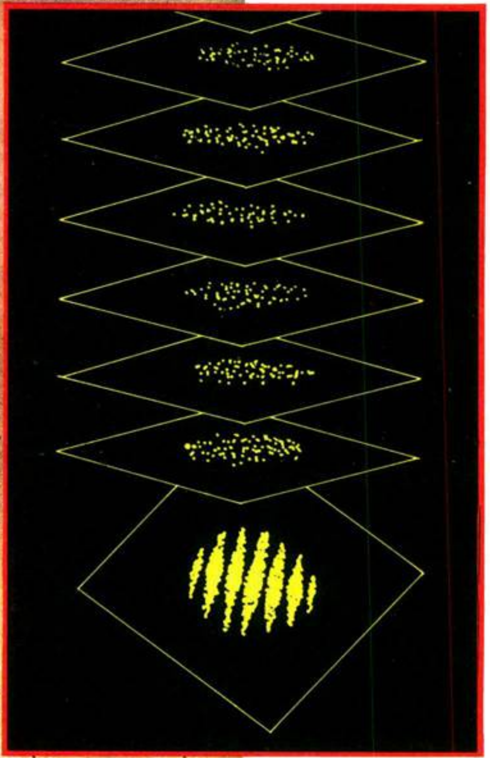
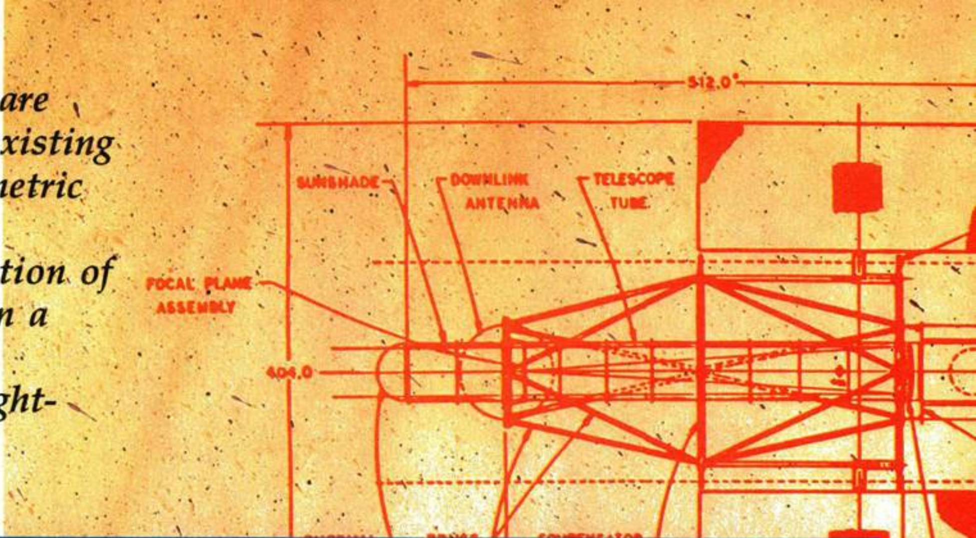
Speckle photograph of a single star. Each speckle is an image of the star, but atmospheric turbulence causes these images to blend together during exposures longer than a few milliseconds.

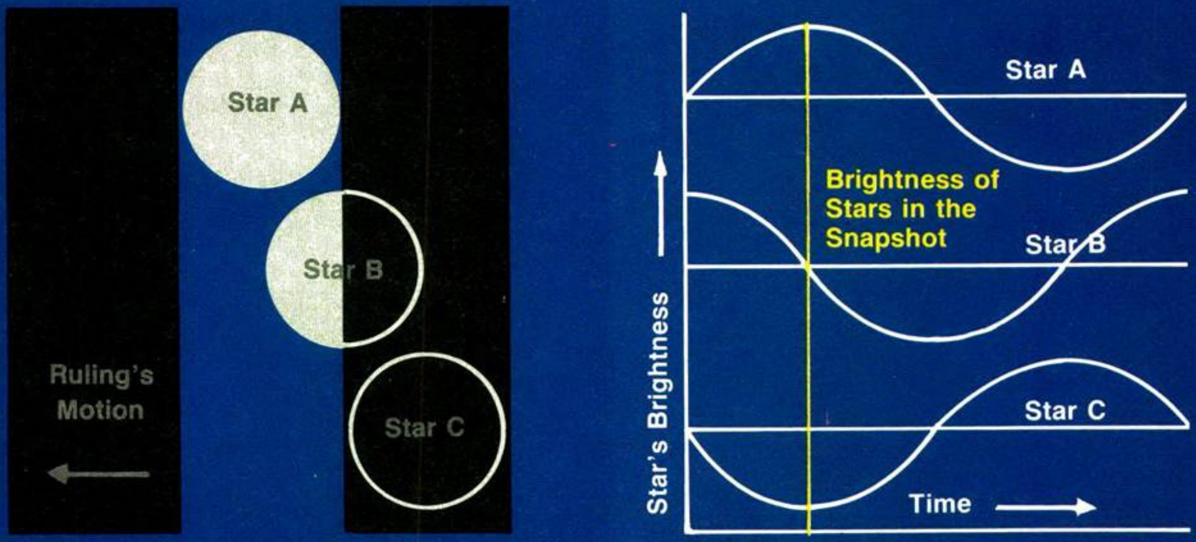


How might speckle interferometry reveal the existence of extrasolar planets? Astronomers could infer the presence of planets by monitoring a binary's interference pattern. The pattern alters as the stars move about their common center of mass and the gravitational effects of any planets would be superimposed on these changes. Astronomers could detect these effects by analyzing many composite speckle photos from a given star.

*Using off-the-shelf hardware and built around an existing spacecraft design, Astrometric Telescope's baseline task is the detection of an Earth-mass planet in a five-year orbit around a star within 32 light-years of the Sun.*



A "snapshot" of three stars in the Astrometric Telescope's field of view.



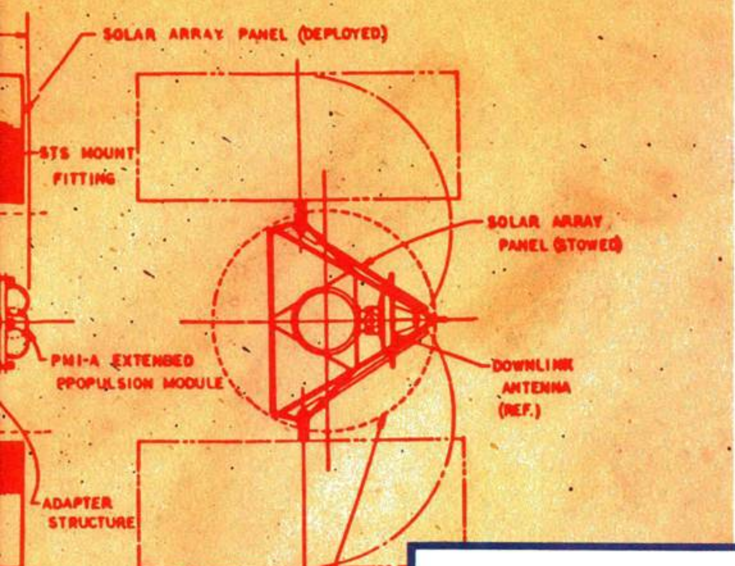
A Ronchi ruling consists of a transparent material onto which regularly spaced opaque lines are etched. As the ruling moves, it alternately blocks and transmits the light from stars in the telescope's field of view. This causes the brightness of each star to vary cyclically. Knowing the space between lines and the rate at which the ruling moves, astronomers can determine the relative positions of all the stars in the field with great accuracy.

moving toward them. Similarly, when the Shuttle was moving away from the Pleaides just before it fell below the horizon, the astronaut would notice that the stars were farther apart. It turns out that this effect can cause apparent relative star positions to change by up to 30,000 microarcseconds in half an orbit! Motions of the Astrometric Telescope must be very well known in order to adequately model this phenomenon.

The telescope's data will also be complicated by the presence of stray light from unwanted sources. One of the most important causes of this "noise" is diffraction caused by structures in the focal plane. The most seemingly insignificant light sources must be accounted for: zodiacal light (sunlight scattered by interplanetary dust); integrated starlight (light from stars unresolved by the telescope); and diffuse galactic light (starlight scattered by interstellar dust). Together, these sources are comparable to about 100 tenth-magnitude stars per square degree. To minimize the sunlight scattered into the telescope barrel, a sunshade will protrude from the end of the barrel; baffles on the barrel's inside surface will absorb scattered light that does enter the tube.

The intrinsic motion of a reference star could be as great as 10 microarcseconds per hour, so its stability over a five-to-ten year survey would be several orders of magnitude below the required accuracy. To solve this problem, astronomers will use between five and ten reference stars for every target star and make many repeat observations. Calibration procedures can be used to deal with systematic errors, while data averaging and increased observing time will minimize random errors.

A very cost-effective way of minimizing observing time would be to develop a double-barreled telescope, with the two Ronchi rulings oriented at right angles to each other. Observing a target in two axes simultaneously would simplify operations, and offer the added benefit of redundancy — each telescope serving as a backup in the event of the other's failure. Lockheed conservatively estimates a double-barreled telescope could survey 100 stars in five years, compared to 50 for the single-barreled design. This 100 percent increase in efficiency would up the total cost by less than 25 percent. The cost of these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SOLAR ARRAY PANEL (STOWED)
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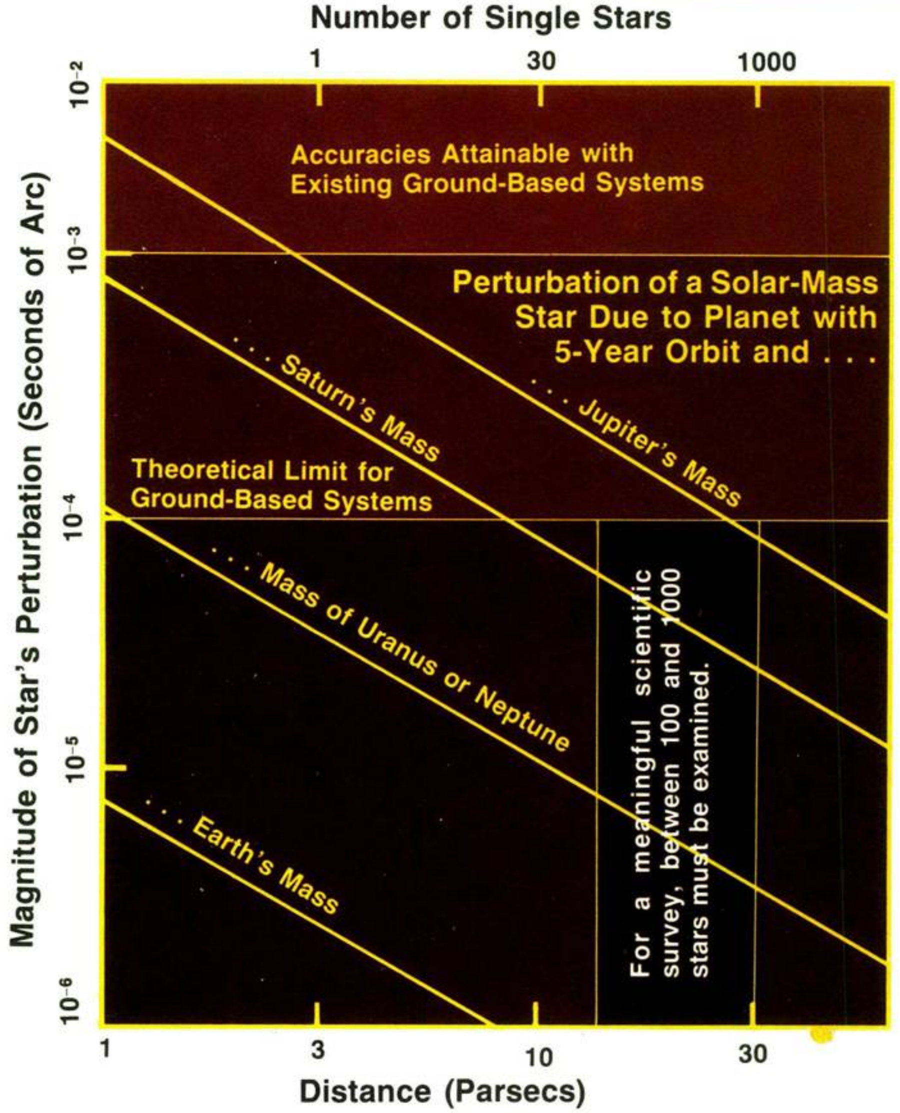
ADAPTER STRUCTURE
IMARY MIRROR, 40°
STS BA



**Only a space-based system could detect moderate to low-mass planets *and* provide comprehensive statistical data.**

*"The technology exists to undertake a scientifically meaningful search for other planetary systems," notes Black. "Our ability to determine whether other stars have planetary systems is limited only by our willingness to invest time, thought, and money."*

missions? In the neighborhood of $200 million for a two-barreled telescope or $160 million for one.

Although the baseline task of the Astrometric Telescope is to detect Earth-mass planets, the instrument might best be used in a search for larger planets. The Solar System Exploration Committee, an advisory group to NASA, has suggested that a pioneering survey program should concentrate on planets about the size of Uranus and Neptune. Such planets could be detected with an accuracy of 10 microarcseconds. At this reduced accuracy level, observation time would be minimized, and many more targets could be studied. "Uranus and Neptune," notes David Black, "are believed to have approximately the minimum core mass necessary for the formation of a gas-giant planet, roughly 10 to 20 Earths." If a survey revealed no such planets, our solar system would begin to seem anomalous. If jovian planets were found in abundance, their sizes and orbital characteristics would, for the first time, provide a range or possibilities — a planetary spectrum — against which our solar system could be compared. Whatever the results, this information would be invaluable.

If, on the other hand, the Astrometric Telescope succeeded in detecting Earth-sized planets around nearby stars, NASA's Search for Extraterrestrial Intelligence (SETI) program would be a major beneficiary. Knowing of even a single extrasolar planet comparable to the Earth would help legitimize SETI, which is perceived by many as an exotic casino game.

It will take 12 to 15 years from the start of a space-based planetary detection program before we have firm data. "Until that data is in hand," says Black, "we have no way of knowing whether our entire scientific effort to understand the origin of the solar system is addressing the right questions." Black believes that the Astrometric Telescope has a good chance of being funded in the next year or two. He is working not only on getting this telescope aloft, but also on pushing the best of the ground-based systems to operational status. Over the next few years, the Earth-bound programs may help to determine which stars are the best targets for the orbital instrument's high-accuracy scrutiny. In some instances, these ground-based systems could even do better than the orbital telescope. For example, the Astrometric Telescope has a limited ability to resolve binaries — and if we hope to determine how planets form, we cannot ignore this stellar majority. But ground-based speckle interferometry is well-suited to this sort of work, and could provide a critical complement to the satellite's results.

"The technology exists to undertake a scientifically meaningful search for other planetary systems," notes Black. "Our ability to determine whether other stars have planetary systems is limited only by our willingness to invest time, thought, and money." In his public lectures, Black has been impressed by his audiences' fascination with extrasolar planetary detection. Many people seem eager to believe in other worlds: perhaps we all can sympathize with Percival Lowell for falling into the trap. But no human imagination could have anticipated Mars as our spacecraft have revealed it — a planet simultaneously Earthly and alien. When our new telescopes are finally ready to unveil the Galaxy's worlds, we might do well to expect a few surprises.

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*Ken McBride is a freelance science writer living in Don Mills, Ontario, Canada.*

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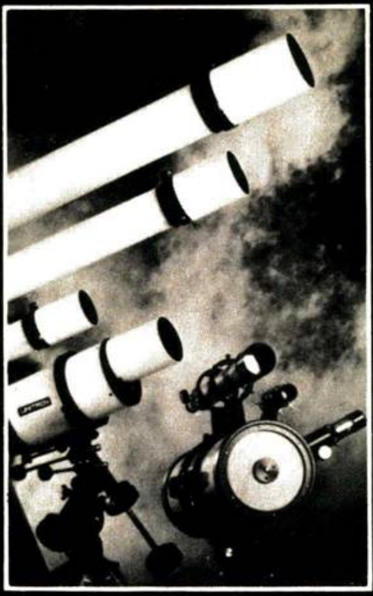

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# ASTRONOMY
# Forum

## In Defense of a Classic

The other night I was out under dark, starry skies. It was a warm, comfortable evening, without any pestering gnats, but with a cool, gentle breeze and a fine, sweet smell about the air. All four of my prized telescopes accompanied me outside. I had lined them up in a neat and perfect row, as proud as any father. Each pointed to one of my favorite celestial showpieces — Saturn, the rapidly sinking sliver of young Moon, the Andromeda Galaxy, and the Dumbbell Nebula. As I gleefully strode back and forth, to and fro, from view to view — re-centering each object as I returned — a blinding flash of light struck my eyes. It wasn't a confused motorist, no; it wasn't a brilliant fireball, no; it wasn't a lightning stroke or a searchlight gone haywire. It was an apparition, a lone visitor, a phantasm like none I have ever encountered.

I asked the strange specter, whose physical appearance was rather insubstantial, what he wanted and why he had the nerve to ruin my night vision. He quickly replied, in ghastly and unsettling low monotones, "You, my good fellow, are a telescope junkie!" Since he had not answered my question, and further had interrupted me to the point where I had lost track of all four objects, I became incensed. "But who are *you*?" I demanded. He responded, "I am the ghost of all amateur astronomers who are still saving their quarters for their first telescope! To cleanse your soul, and avoid being cast into astronomy hell for eternity" — a place where it is overcast each and every night, he later explained — "you must give all of your instruments save one to poor, budding young astronomers!"

By this time I was genuinely upset, having been scolded severely by a thing or being about which I knew nothing. Stirrings of the most horrible fear arose inside me, a fear that caused my heart to palpitate and my entire frame to shake. "Go on, choose!" the demon said to me, as he pulled me in front of my four prized possessions. No, no, not my 10-inch Dobsonian. It has shown me spiral structure in M-51 and resolved M-13 into thousands of specks of glitter. No, I don't want to part with it. My 5-inch rich field telescope brings into view wide, bright starfields of the Milky Way, and may bring me immortality as the discoverer of a comet some day. How can I part with it, I ask you? My 6-inch Newtonian is the perfect all-around telescope, highly portable and versatile for nearly any application. No, no, I mustn't lose the use of it. Sitting beside these instruments was my lowly little 3-inch refractor, the telescope that had introduced me to the stars many years ago, when I knew not what they were about. Its lens needed a cleaning, and its mount a little tightening, but it still provided me with crisp, clear images.

> *" 'Go on, choose!' the demon said to me as he pulled me in front of my four prized possessions."*

Perhaps sensing my apprehension, the spirit granted me an hour's worth of observing with the four telescopes before I had to decide. I thought this particularly human of him, and happily trained all four scopes on a variety of planets and deep-sky objects. The ghost, with ill-defined tattered bits of clothing draped over parts of his weary, pitted bones, sat down on an old log and lit up a cigarette. I nearly said something to him about the danger of smoking, until I realized . . .

Suddenly, with a violent twitch, I woke up. It had all been a terrifying nightmare — I didn't really have to give away my telescopes. But that episode starting me thinking that if I *did* have to keep only one telescope — as insane as it may sound, it would be the 3-inch refractor. It's the perfect little friend to bring along out under the stars; it's beautiful to look at, has the most even disposition of any telescope I've used, doesn't give me any hassle with adjustments, and is always ready when I am.

Yes, I admit it. I'm a sucker for a pretty face, and my 3-inch refractor has one. It looks like a telescope. Its proportions are beautiful. I know you'll say that such vanities are astronomically irrelevant, but I'm an amateur — a lover. My sensitivity goes beyond attacking the heavens with any light bucket that happens to work. There is a sympathy between the beauties of the heavens and the observer with a beautiful instrument. There is a rightness about it, as though the starry sky appreciates beauty, too. Have you ever noticed that even the most pragmatic cost-per-aperture devotees will cluster around a long-focus refractor at a star-party? Certainly the telescope's elegance is one reason for this.

But there are other reasons, too. My 3-inch refractor is not only lovely to look at, it's lovely to look through. Although it won't show what my larger telescopes show, it reveals far more than I have any right to demand — and quite well at that. Not only will it display all of the Messier objects under dark skies, its air-spaced optics are large enough for observing the Moon, Jupiter, Saturn, and with proper precautions, the Sun. When I desire

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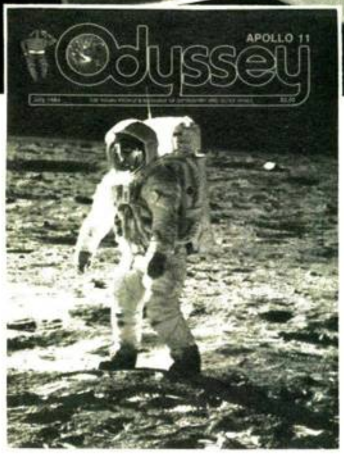

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something special, it takes me to the realm of double stars. Can anything beat the view of a close pair in a small long-focus refractor? There are thousands within its grasp, and the refractor's celebrated image-steadiness makes it worthwhile to view them. Even on nights of only fair seeing, doubles like Castor, 70 Ophiuchi, and Epsilon Lyrae are resolvable. They look like double stars instead of double blobs.

And what about that poor old Moon, so neglected by today's amateurs? Even though I have never gotten around to "serious" lunar observing, the sight of pointy black shadows of the lunar Alps on the floor of Mare Imbrium is breathtaking. Talk about contrast! What's more, those sharp details stay put. Although lousy seeing makes any telescope perform poorly, my 3-inch f/16 does surprisingly well on those marginal nights when my larger scopes provide only quivers and frustration. That's why I say that my 3-inch has the most even disposition of all my scopes.

My scope doesn't require the best of conditions to perform well. When I set this scope up and find it difficult to get a good focus, I know it's the atmosphere and not the collimation. I don't have to be a technician. I am delivered from the perfectionist's urge to tinker and the subsequent frustration and loss of observing time. I am told quite simply that I just have to make the best of a bad night instead of making a mess of a good scope. That's another thing I like about my refractor. It doesn't hassle me.

There's still more. My 3-inch has another virtue. It's always ready when I am. If I have a busy tomorrow facing me and can afford only an hour of observing time, my refractor gives me the greater part of that hour. It sets up in five minutes and usually cools down by then. Many are the nights that I have split several colorful doubles, enjoyed Cassini's division, and been well into following a transit of the Great Red Spot while my friends are still tinkering with their scopes and allowing them to equilibrate. I'm old-fashioned. I believe that amateur astronomy is about observing, and this telescope lets me do it. Once upon a time the 3-inch refractor was the amateur's favorite telescope. In my book, it remains a classic.

*Robert Allen Buss*
Dickinson, ND

## Planning a Star Party?

With the cool, comfortable breezes and crisp skies of autumn upon us, it's time to really enjoy star parties again. Sure, everybody flocks out to lonely dark sites during the summer, but the absence of hot, muggy air and hungry mosquitoes makes fall the most comfortable time of year to gaze up at the stars. The wide, nebulous glow of the summer Milky Way still hangs overhead, showing off Cygnus and Sagittarius and all of their treasures, and late in the evening old friends like Andromeda and Pegasus return, bringing innumerable galaxies with them.

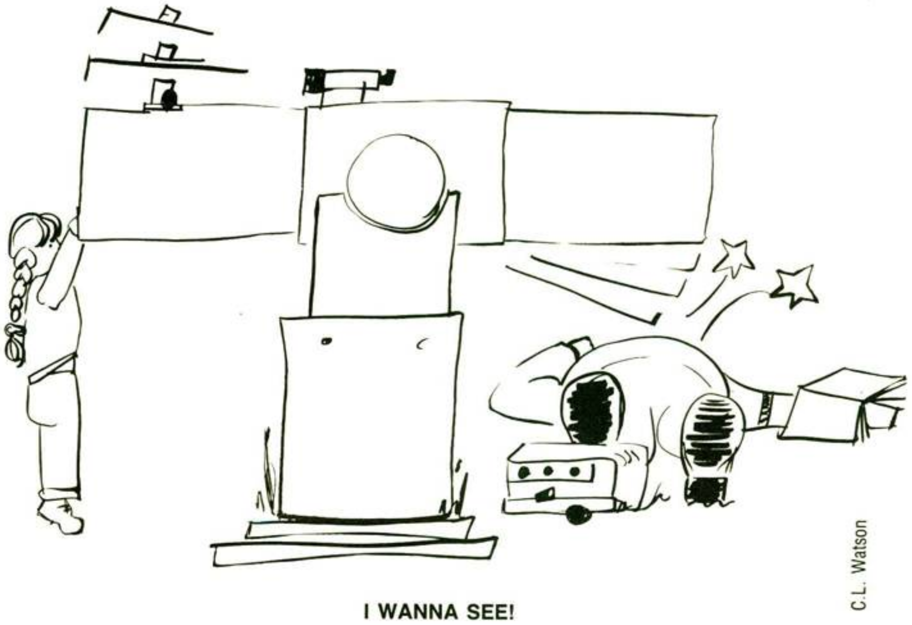
Imagine that you're going to a star party tonight. What should you do? What should you look at? How should you handle naive questions from non-astronomer friends? How protective should you be of your expensive toy, which many people will invariably monkey with? After giving it considerable thought, I've formulated a few rules of thumb for attending any star party.

Let's start with *equipment*. As everyone with any measure of common sense knows, the longest lines always form behind the largest telescopes. Owners of big "light buckets" should encourage people to use smaller telescopes as well, as they show off some objects better than large scopes. But trying to tell that to someone awestruck by seeing a large scope for the first time is like saying, "Nah . . . you don't really want a silver Rolls convertible . . . try this '65 Chevy Corvair instead!" If you've chosen a crisp, dark night, a few views of planets or bright deep-sky objects through the 3-, 4-, and 6-inch scopes will convince the uninitiated that gigantic apertures aren't necessary for general observing.

When showing friends astronomical objects, always use low-power eyepieces. People normally have trouble adjusting to eyepieces, and they certainly don't need to start their adventure in astronomy by attempting to peer through a 4mm Ramsden that gives dim, blurry, constricted images. If you want to increase the scope's power, insert a 2x or 3x Barlow lens and keep comfortable eye relief for your befuddled guests.

What about a clock drive? Won't you need one? Not really. It's convenient and saves you from re-centering the object every time someone bumps the scope or the Earth rotates a bit. (As a general rule, all children bump the telescope at least once. For this reason you might bring along a short ladder so they won't bump it as much.) But if a lot of people are present, those precious moments of re-centering usually constitute all the view *you'll* get during the course of the night. Come to think of it, even if you've got a clock-drive, don't use it.

Provided your telescope is sufficiently large, brightly colored, unusual looking, or otherwise eye-catching, you'll probably attract a small crowd of onlookers. Now, what are you going to show them? A safe bet is to start with bright planets — if possible Saturn or Jupiter — and the Moon. Everybody loves the Moon — they're familiar enough with it as a naked-eye object so that through a telescope its marvelously detailed surface is believable and yet stunningly artificial-looking. Catching it around First Quarter allows you to view it for a while — particularly around the terminator — and then move to pro-



C.L. Watson

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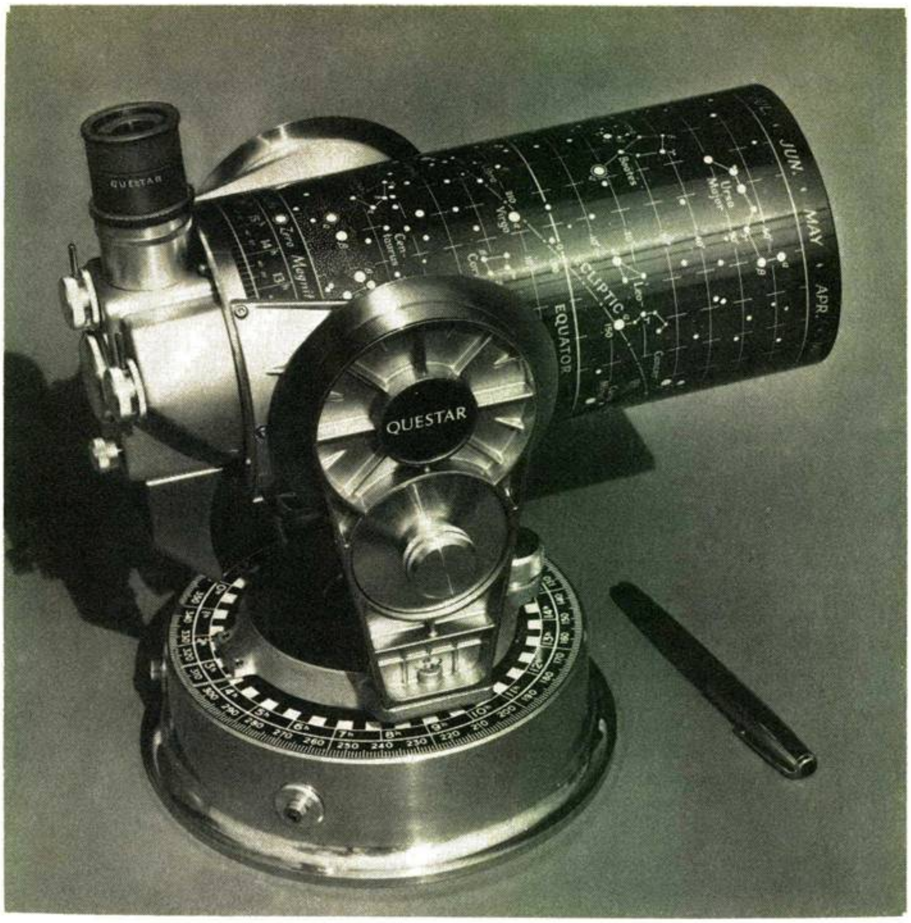

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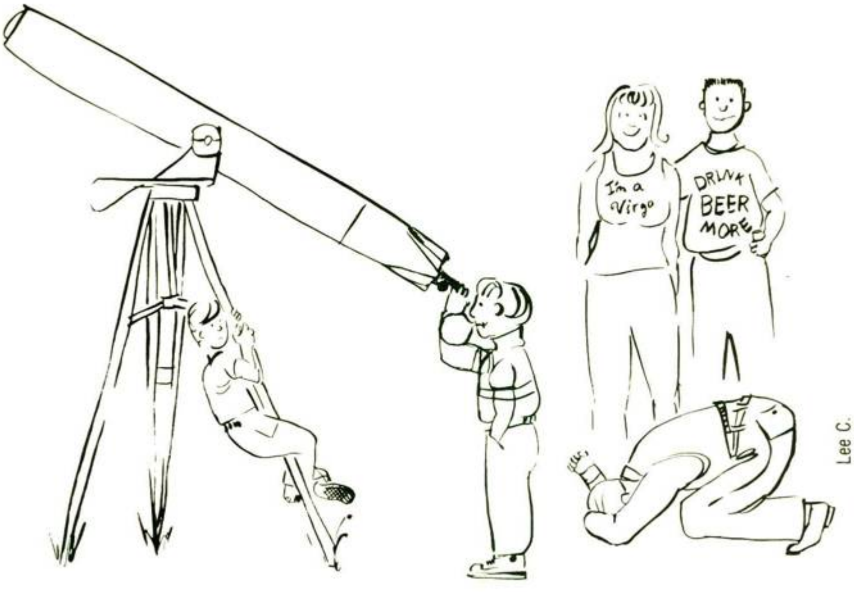


Lee C.

gressively fainter stuff as the night progresses and the Moon sets. Saturn and Jupiter are point sources as naked-eye targets, and consequently appear completely alien to most first-time lookers. A none-too-small percentage of the people who first see Saturn's rings actually believe, if only for a short time, that the image they're seeing is trickery!

Naturally, if the sky isn't dark, avoid faint deep-sky objects. Double stars and open clusters are observable from practically anywhere, but 11th and 12th magnitude nebular objects are not. Deep-sky observing is an acquired taste: images of far-away galaxies are subtle even to fairly experienced observers under good transparency, so needless to say they'll be less than impressive to people who've never looked at anything with a telescope.

You can even set up during the day and show people the Sun. Cover or remove all finder and guide telescopes, and instruct the crowd about the great danger of looking at the Sun through a telescope. You really shouldn't let strangers be around or look directly through scopes, even if they're fitted with solar filters. If you want to look at the Sun through a solar filter, do it alone. Then if something happens, you know who to blame — and you can't sue yourself.

Be prepared to answer a barrage of questions about astronomy and related subjects ranging from astrology to UFOs to relativity to life elsewhere in the universe. If you're on the ball, you'll do some homework and answer questions in terms that anyone can relate to:

Q. *How big is our Milky Way Galaxy?*

A. If our solar system were the size of a baseball, the Galaxy would cover the entire continent of North America.

Q. *How far away is the nearest star?*

A. The Alpha Centauri system lies 4.3 light-years away; a brand-new Mercedes, operating at a nonstop 55 m.p.h., would make the trip in just under 52 million years.

Q. *What is Saturn made of?*

A. Saturn is primarily composed of hydrogen and helium, and consequently has a very low density. If we could harness the planet and drop it in a giant bathtub full of ordinary water, it would float!

Q. *Do you believe in UFOs?*

A. Yes, I believe that some people definitely see unidentified flying objects.

Q. *Do you believe that UFOs are visiting spacemen?*

A. Of course not.

The list could go on and on, trampling on the heels of thousands of related subjects. You've just got to be ready, honest, polite, and easy to talk to. No one likes a condescending amateur astronomer at a star party. (Or anywhere else, for that matter.)

You might think about crowd control. I hadn't until late one night when I woke up, got off the ground, dusted myself off, and cleaned the cotton candy and spilled beer off my poor telescope. Since that disastrous county fair, I've recruited a couple of helpers to keep people in control. My friends also answer questions and point out constellations with their flashlights — an enormous help when the crowd grows to a large size.

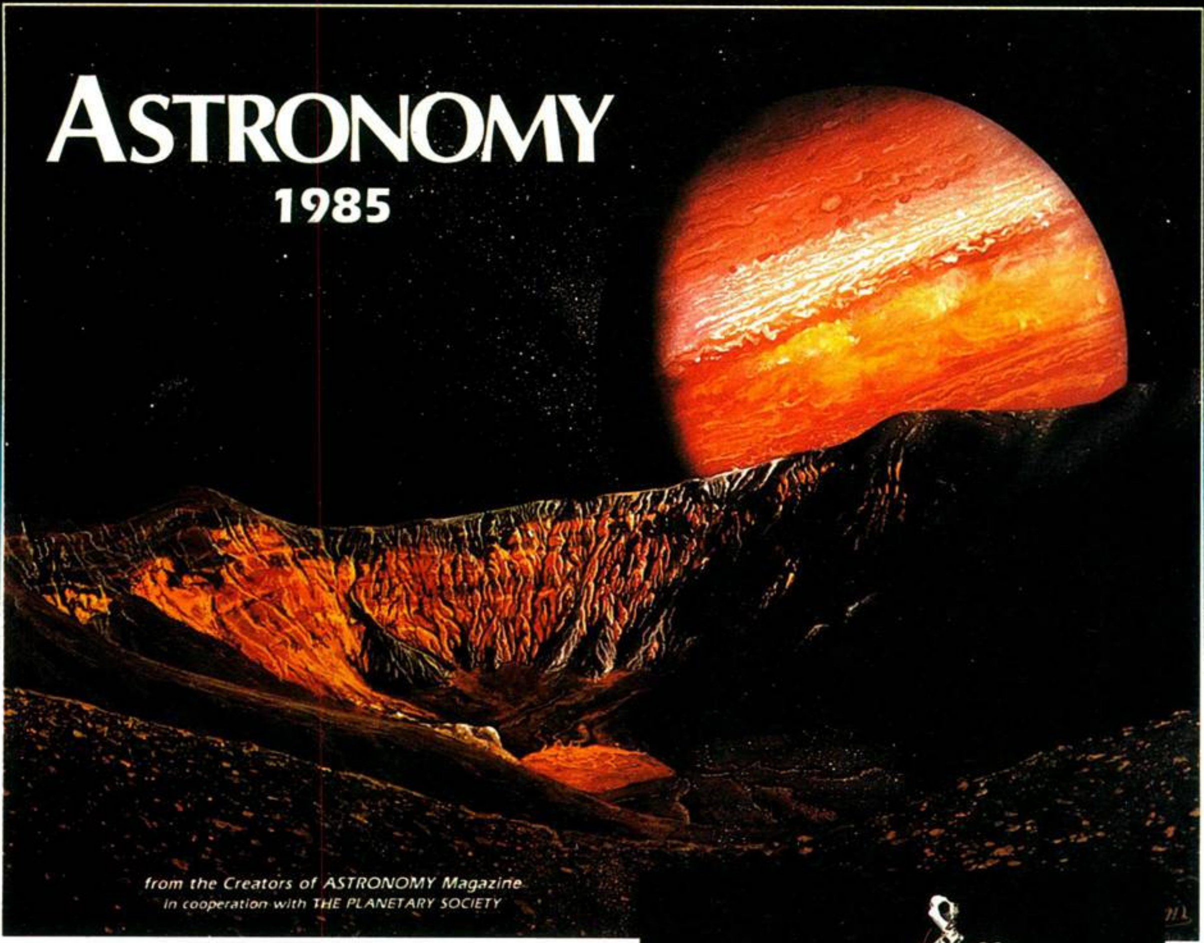
With a little luck you will have a few people who are interested enough to want to know more. I keep a few handouts ready: a list of astronomical publications, some projects in naked-eye and binocular observing that are fun and easy to do, and a list of astronomical events like eclipses, meteor showers, comets, and conjunctions, along with suggestions on viewing and photographing these events.

With good weather, a good crowd, a variety of telescopes, and a little patience and understanding, you can have fun observing while you bring some of the delights of astronomy to someone not fortunate enough to be an amateur astronomer already. If you ever become jaded at questions people ask or objects they want to see, think back to when you first thought about the stars. I'll bet someone showed you Saturn, or Jupiter, or the Moon through a telescope — didn't they?

*Jim Baumgardt*
Burlingame, CA

C.L. Watson

**Let's discuss the spiral galaxy NGC 891, located between Gamma Andromedae and the open cluster M34 in Perseus, at 02193n4207.**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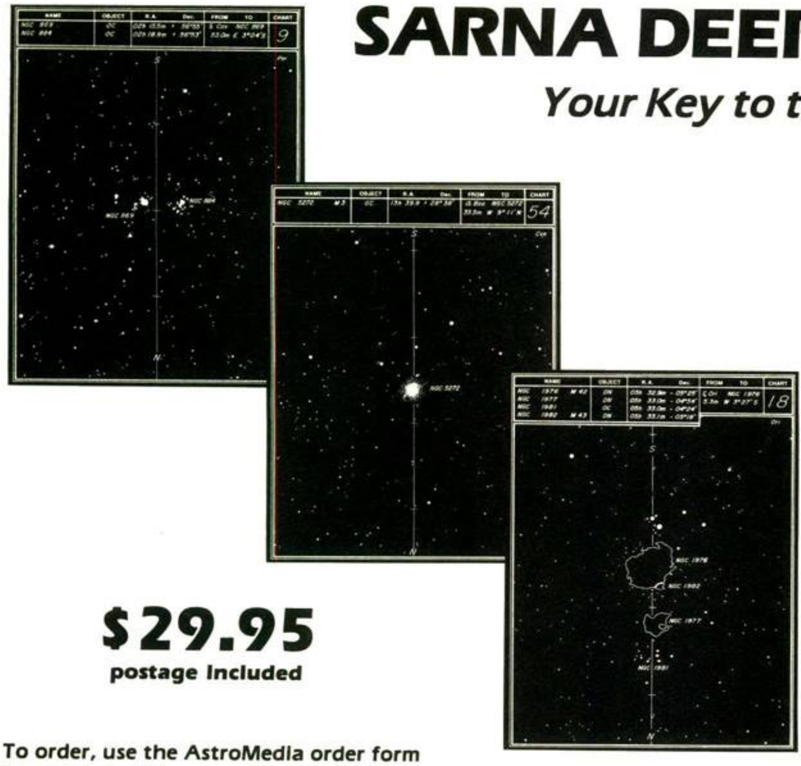

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# ASTRONOMY
# In Focus

## Aliens: Mirror of Human Values?

Sir / Thank you. Richard Parlour's article (Forum, July) has focused on a widely ignored but important topic.

Being a professional psychotherapist and a very amateur astronomer, I'd like to carry a point in the article further: not only do we know nothing about aliens, but even the way we think about them reflects our own values and perceptions.

It's certainly true, as Parlour writes, that "technological excellence does not imply moral excellence." But moral excellence exists only in human minds. There is no morality in nature — the universe is neither good nor bad, it just *is*.

Although human beings need ideas of morality, it doesn't follow that aliens operate in any kind of similar moral framework. We have no idea of what motivates aliens — it may have nothing to do with good or evil, or anything else we take for granted. And because we have no idea of what values they might have, we also have no idea as to how they would interact with Earthlings. To say they would be good, bad, scientific, or emotional is simply a projection of our own inner fantasies and wishes. The simple truth is we don't know and we cannot know until we encounter an alien.

The wish for a strong, powerful figure to rescue us from our difficulties is very deeply embedded in the human psyche. But in this case, where we could easily be overwhelmed, contact might prove suicidal. I believe it would be best to attempt contact only under circumstances which do not jeopardize the entire living population of Earth.

Roland Ostrower
New York, NY

## The Sundog Difference

Sir / The caption for the figure on page 46 of the May issue of ASTRONOMY contains an error. We do *not* see "the sides of a halo when ice crystals align horizontally, resulting in a 'sundog.'" While refraction through the sides of horizontal, hexagonal ice platelets does produce the sundogs, these are separate phenomena from the halo, which they touch only when the Sun is on the horizon. They diverge from the halo as the elevation of the Sun increases, reaching a maximum angular distance from it of nearly 29° when the solar elevation reaches approximately 61°. At higher solar elevations, the sundogs disappear because total internal reflection occurs in the crystals. A lucid and beautifully illustrated description of this and other optical effects of ice crystals in the atmosphere is given by Robert Greenler in his book *Rainbows, Halos, and Glories*.

John Pearl
Bowie, MD

## Creation and "The Gap"

Sir / Regarding the item in AstroNews (May 1984) entitled "Creationism and Astronomy," I felt I had to let you know there are Christians (Creationists) who do not believe that the Earth and universe are only 6000 years old. We believe what is called "the gap theory," the gap being between the first and second verses of the first chapter of Genesis.

I personally inject about a million years in there, but do not rule out *any* possibility. Only God knows the actual amount.

Nor do all Creationists (Christians) believe the radius of the universe to be 5000 light-years. We "gap theory" Christians believe the radius to be infinite — there is so much out there that it couldn't possibly fit in a sphere with a radius of only 5000 light-years.

We don't base this on the hearsay of atheistic astronomers, but rather on what we can see with our own eyes — what anyone can see through a telescope.

There are also "6000 year" Christians who believe the universe to be infinite. It could be that at the moment of creation God allowed light to travel instantaneously to all parts of the universe. This only acknowledges that God has no limits.

I want my fellow Christians to know that I am not dogmatic about my beliefs. If God should ever tell me otherwise, I'll believe him.

Jim Baker
Hagerstown, MD

## Amici Prisms

Sir / In response to Jessie Carroll's letter (May's In Focus), Amici prisms are available through Edmund Scientific, 101 E. Gloucester Pike, Barrington, NJ 08007.

They are available, in 1¼" diameter only, as part number E50,247, and are priced at $29.95 in the 1984 summer catalog.

Edmund advertises only sporadically in the astronomy press, but they are a good source of astronomical parts. And they make excellent mirrors, too.

Jan Owen
Phoenix, AZ

## Comet Names

Sir / Allow me to reply to Jim Loudon's letter (In Focus, May) on the IRAS comets. He is correct that the first comets discovered with (not by) a spacecraft were the Solwind comets. Nonetheless, the Solwind comets were never observed from the ground, so Robert Burnham may be forgiven for his description of Comet IRAS-Araki-Alcock as the first comet discovered by a satellite.

I suggest that Comet IRAS 1983o was the most significant discovery in this respect, since IRAS' observations on July 17 and September 1 allowed

C. Bardwell to calculate an ephemeris from which it was optically recovered by Gilmore on September 11.

Naming comets is always an emotive issue — after all, who doesn't want a comet named after him? — but the IRAS discoveries were due to a team effort in which Simon Green (University of Leicester), Brian Stewart and Jack Abolins (Rutherford Laboratory), and H. Aumann (JPL), as well as myself, each made significant contributions. Indeed, the whole IRAS project was a tremendous example of how men and women from different nations can work together toward a common goal.

As such I would not regard naming a comet after IRAS as a dubious honor, but rather as a tribute to the efforts of everyone on the IRAS team. I may be the only man alive to discover six comets and not get my name on any of them — but, truthfully, I really don't mind!

John K. Davies
University of Leicester
Leicester, England

### Automated Astronomy, Part II

Sir / The letter from Jan Owen in the July In Focus worries that, first, astronomers might not be *looking* through automated photoelectric telescopes (APTs), and second, they might be *sleeping* while the APTs are working. I would like to confirm the worst of Jan Owen's fears!

Even if one wanted to, it is difficult for humans to look through APTs. For APTs to operate, it is necessary for the microcomputer to look through the photoelectric "eye," and it is difficult for humans to do so at the same time. Also, some APTs, such as the first one developed at the University of Wisconsin in the mid-1960s, do not even have an eyepiece for a human to look through. As astronomers can't look through the APTs while they are in operation, there is no reason why they should stay up and watch the telescope — and so they generally sleep at night.

While some beauty is certainly lost to human eyes as a result, let me suggest the following mitigating circumstances. First, there are thousands of human observers around the world soaking up the beauty of the heavens every clear night. On the other hand, there are just a few APTs in operation that allow *computers* to enjoy the beauty of the heavens. Second, the direct visual beauty in observing the same set of individual stars pales rather quickly. Finally, to the trained eye and mind there is a certain amount of beauty in a plotted light curve, not to mention the excitement of discovering a new variable star.

The precise photoelectric "eye" can see many interesting (and, to some of us, beautiful) things about stars that the human eye cannot. Perhaps two well-worn cliches apply here: beauty is in the eye of the beholder, and to each his own.

Russell M. Genet
Fairborn Observatory East
Fairborn, OH

### Neglected Cluster

Sir / In your monthly Backyard Astronomer section, you have featured the constellation Perseus several times, but I don't recall ever seeing the open cluster NGC-1342 featured — it's a big, splashy group of stars about midway between Xi (ξ) and Rho (ϱ) Persei. On my hikes through the woods with my dog, I take my 7 x 50 binoculars, which show it as a dazzling sight, similar in size and actually more resolved than M-35 in Gemini!

James H. Haas
Houston, PA

*Mr. Haas / We would certainly like to feature all bright and easily observed objects in our Backyard Astronomer section, but the available space limits us to about 15 or 20 objects per constellation. Thus we try to achieve a balance between types of objects in a given constellation — double stars, variable stars, open or globular clusters, emission, reflection or planetary nebulae, and galaxies. This selection of objects lets us cover most of the bright or unusual deep-sky objects in a given area of sky; if you're eager for more to look at, why not subscribe to AstroMedia's* DEEP SKY *magazine?*

### Ooops!

Alpha and Eta Ursae Majoris are *not* members of the Ursa Major Moving Group, as we noted in June's "Viewing the Summer Constellations."

In the August issue, the Milky Way on our map of Sagittarius was inverted. We apologize for relocating part of the Galaxy!

## Behind the Scenes | Watching the News

ASTRONOMY's editorial library receives an impressive number of other magazines. There are major astronomy magazines from all over the world — Britain, France, China, Italy, the Netherlands, Japan, Germany, to name just a few countries where amateurs pursue the hobby of astronomy — plus an amazing number of society publications and club newsletters. Besides the magazines intended for the astronomy hobby, of course, we also receive many professional scientific and astronomical journals.

The influx is more than any one of us here at ASTRONOMY can possibly read — even if we could fluently read all the languages! Whenever I start to feel that there are too many astrologers and too few astronomers, I settle down to peruse this rich reflection of worldwide astronomical activity.

Of course, we use this material to keep up with what's going on. The scientific journals hold the output from astronomers wrestling with the complex problems of modern astrophysics — write-ups of computer models of black hole accretion disks, fresh spectra of exotic objects in the Magellanic Clouds, tables of photometric brightness data, lists of radio sources, the latest maps from the VLA, and a new determination of Neptune's rate of rotation.

We watch our magazine counterparts from other countries to see if they are offering their readers information or services that we'd like to offer you, our readers. Frequently we find that they are apparently watching us, too. Flipping the page, we suddenly see artwork or a diagram that seems very familiar. Such use is, of course, the "sincerest form of flattery," and more often than not we find ourselves appreciating it.

The amateur publications and club newsletters from around the world make fascinating reading. It's fun to know what people in Vermont, Sao Paulo, Houston, and Rome are doing — the star parties, observatory fundraising drives, fix-up and paint-up parties — or to know the club treasurer is asking members to pay their club dues by October 15 — or else!

So there's a world of activity in astronomy. The next time you feel more isolated than you'd like in your hobby, remember that there's something you can do about it. Get yourself on a few mailing lists, or talk your local club into taking out subscriptions to some "exotic" magazines. Get tied into the world of astronomy.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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# LUMICON FOR HIGH PERFORMANCE

## ASTROPHOTO OF THE MONTH

**Barred Spiral Galaxy NGC 1300** in Eridanus. Photo by David Healy using a Lumicon Giant EASY-GUIDER and hypersensitized 2415 film. 1 hour exposure. Celestron-14 at f/7.

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*(apparent field of view in parenthesis)*

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| D-19 B&W Developer, 1 gal. | | $5.95 |

# High Resolution Lunar Photography

Photography in Astronomy

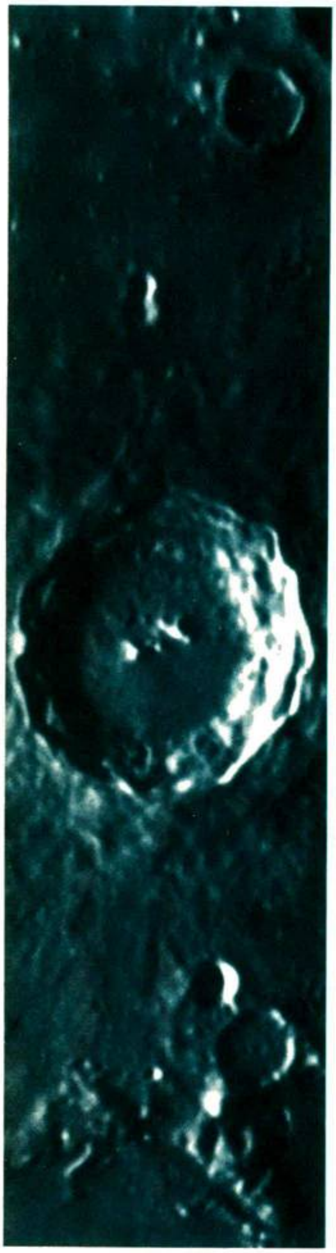
by
Jean Dragesco

Though the Moon is a popular visual target for many backyard telescopes, most astrophotographers seem to think that taking lunar photos is a waste of time. It looks too easy, they say. Or they tell you that the Moon is a dead world, nothing changes there, and spacecraft have done the job better anyway. To me, however, the Moon represents a very attractive subject because lunar photographs are so spectacular. Nowhere else in the sky do you get such infinitely varied combinations of light and dark, and every night presents a different appearance.

Most beginning astrophotographers are disappointed with their first attempts at through-the-telescope lunar photography. Instead of dramatic vistas, they get washed-out or blurred detail overlaid with fuzzy grain. In many cases, they've simply used the wrong equipment and materials or are going about it in the wrong way. And many quit before they acquire the skills to produce consistently good results.

First of all, you need a telescope with an equatorial mounting. In this respect, detailed lunar photography is no different from photographing dim nebulae and galaxies. (Yes, you can take fairly good unguided snapshots of the Moon with a Dobsonian, say, but the photos won't have enough image quality to allow blow-ups of small areas of interest.) You'll also need a camera-to-telescope adapter that lets you insert eyepieces for projection magnification and a couple of good-quality eyepieces, including a Barlow. Kellners, orthoscopics, and Plossls are good designs and have flat fields for clean, sharp focus. You'll need a drive corrector, but although off-axis guiders or separate guidescopes are helpful, they are not necessary, since you'll be making the tracking adjustments by looking into the viewfinder of your camera.

Equipment aside, high resolution in astrophotography comes as a direct result of good atmospheric conditions: *seeing* determines everything. Good seeing, in turn, depends largely on the site you choose to observe from. Circumstances have led me to equatorial west Africa (the city of Cotonou in the Republic of Benin); though quite warm, the climate there offers generally favorable conditions with steady layers of air. Moreover, its latitude of 6° north means that the Moon and planets pass through or near the zenith. But you don't have to travel to Africa to get good lunar photos! Nearly every spot on Earth will offer good or better seeing at least part of the time. The trick comes down to recognizing good seeing when it happens and seizing the opportunity.



**The hummocky ramparts forming Copernicus' ejecta apron greet the morning Sun. "Small" hills about 4000 feet high dot part of the crater's floor; the walls, polygonal in shape, have formed terraces on the inside where material has slumped. The photo, which has south at top, was taken February 4, 1982, with a 14-inch SCT at f/60, and XP1 400 film exposed for 3 seconds. All photos by the author.**

A convenient test to see if the Moon is "photo-steady" is to train your telescope on the Moon. Put in your highest magnification eyepiece and find a small craterlet or mountain peak. Focus carefully and observe the object closely. (A guiding eyepiece with a cross-hair makes the test easier, but it's not strictly necessary.)

Bad seeing, if present, will soon become evident. When the movement of the image is less than the object's own diameter during a few seconds' time, the seeing is good. (Watch out that periodic errors in your clock drive don't masquerade as bad seeing — drive errors occur in an east-west direction; bad seeing is random.) On the other hand, if you look in and see that the mountain peak is dancing across 3 or 4 arc-seconds or if it "boils up" and becomes unsharp, *forget photography*. You may as well pack it in — or plan to spend your time just looking.

You might find this the hardest part of

the whole exercise. Some nights will seem almost good enough, and you'll be tempted to try a frame or two. Go ahead, but you'll soon find there's little use in shooting fine detail when the fine detail won't sit still. You must be very patient, especially at sites that offer only so-so conditions. You may find perfectly stable seeing only two or three times a year, or even less.

Some observing sites are inherently unfavorable for good seeing — on the slope of a hill, for example, where winds can be turbulent. Look for a site that has a smooth airflow over it. Good sites often have lots of grass, ground-cover, or other low vegetation around them for thermal stability. Avoid parking lots and other large expanses of concrete or asphalt. These radiate heat for hours after the Sun sets, destroying good seeing. Also avoid pockets and depressions in the land. Hollows tend to collect heavy, moisture-laden air, and dew will soon be a problem. The crisp clear nights that follow the passage of a cold front are also bad — the transparency is often superb, but seeing terrible. Instead, try one of those warm hazy nights that blot out all but second-magnitude and brighter stars. These can have excellent seeing.

### The Association of Lunar and Planetary Observers

The Association of Lunar and Planetary Observers (ALPO) offers a chance for backyard astronomers interested in the Moon and other solar system objects to coordinate their observations, visual and photographic; write to ALPO, Box 3AZ, University Park, NM 88003. Membership costs $12 a year and includes six issues of *The Strolling Astronomer*, their bimonthly journal.

When you take whole-disk lunar photos, the requirements for good seeing relax a bit because 2 to 3 arc-second resolution is sufficient. But if you are trying to photograph the Triesnecker rilles or Schroeter's Valley near Aristarchus, you'll need perfect conditions. Oddly enough, the diameter of your telescope's mirror is somewhat second in importance. Very nice lunar photographs can be made with a 4-inch refractor or a 6-inch reflector, assuming the optics are good, the mount stable, and the driving mechanism excellent. But big diameter telescopes (12-inch or larger, say) have the advantage of brighter images; this means you can shorten the exposure, use finer-grain film, or go for a longer f/ratio and higher magnification than you might with a small scope. In addition, large mountings tend to vibrate less under the influence of the wind. (Wind can be a real enemy; it happens 8 days out of 10 in Cotonou. You have to photograph in the interval between gusts or construct some sturdy wind screens.)

My Celestron 14 telescope gives satisfactory results as far as optics are concerned. The photographs I get with it are much better than those I obtained with a C-8, which is less stable and has a dimmer image as well. People sometimes criticize the big central obstruction of Schmidt-Cassegrains (36% for the C-14) as interfering with optimal resolution, but I find atmospheric limitations are far worse.

The greatest shortcoming of most amateur telescopes is shaky mountings, which cause a high degree of wind sensitivity and vibration. The C-14 weighs only 200 lbs — very nice for transport to remote sites — but since I use it on a concrete pedestal at one location, I would rather it weighed three times what it does. The fork, too, is springy, and particularly so in Benin, where it is quasi-horizontal.

After seeing conditions, the most important consideration is the precision of the drive mechanism. Unfortunately, the drive of my C-14 is not sufficiently precise for high-resolution photography, even after I have adjusted it to run at the lunar rate — you may have the same problem! I have had to improvise a technique whereby I check and correct the tracking every other frame. To begin, I place a small craterlet in the viewfinder of my camera next to a vertical line on the focusing screen grid. Usually a drift in right ascension soon appears, which I work on with the drive corrector until I obtain a perfectly immobile image.

I then take two negatives in rapid succession and return to the viewfinder. Generally the crater soon starts drifting once more to the east or west, and I make a new adjustment. The tedious correction process is necessary because high-magnification lunar photographs demand exposures of several seconds — and for that, constant attention to, and adjustment of, the drive rate is essential.

Of course, focusing must be very precise, too. I no longer use an ordinary ground-glass and microprism focusing screen, preferring instead a transparent one that has a reticle (grid). I've used several cameras in the past; currently I have a Nikon F3 with a 6x magnifier on the viewfinder.

A common contributor toward unsharp astrophotos is the camera shutter. In fact, you should never use the camera's own shutter to take the picture unless you're shooting at 1/250 second or faster. Many amateurs think (and the directions written by some manufacturers leads them to believe) that it is enough to buy a T-mount adapter, attach an SLR, and fire away. Not so! The vibration caused by the mirror flipping out of the light path will certainly cause vibration and blurred photos.

To make an exposure, I first cover the top of the tube of the telecope with a stiff piece of lightweight black plastic. Next, I open the camera's shutter on B. I lift the black plastic piece an inch or two off the end of the scope, wait a few seconds to let the last vibrations stop, and make the exposure by sliding the plastic aside for the 1 to 3 seconds most photos run. (Be careful you don't touch the telescope!) I re-cover the scope with the plastic to end the exposure and close the camera shutter. After advancing the film, I make a second exposure right away, and then it's back to the viewfinder to see how the drive is doing and how the seeing's holding up.

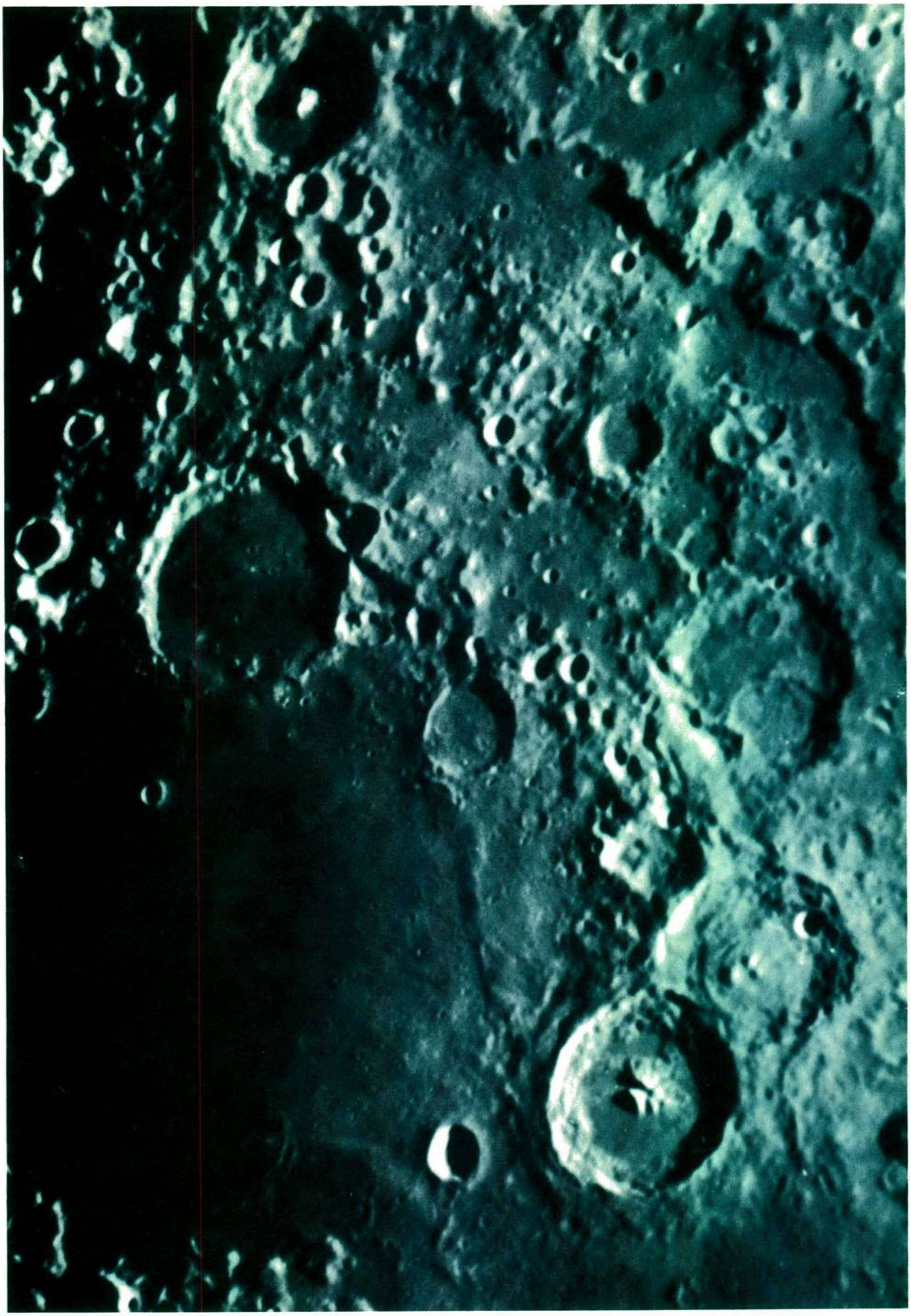
I usually take 8 to 12 frames on each lunar subject. After developing and examining them with a 10x magnifier, I pick the best for enlargement. On a typical 36-exposure roll, I get only 3 to 4 useful frames. Out of every 100 negatives that I enlarge, only 15 or so are *really* good. Lunar photography requires not only persistence, but also many meters of film and a lot of photographic paper!

**Mare Nectaris is one of several maria that fill ancient impact basins; note the telltale concentric scarps that surround it. The crater Fracastorius (left center) formed after the main impact and subsequently had its wall breached by the mare basalts that also flooded its interior. Photo taken November 16, 1981, with a 14-inch SCT at f/36, and XP1 400 film exposed 2 seconds; south is up.**

To photograph the entire lunar disk, I use high-resolution film such as Technical Pan 2415 or Kodachrome 25. I develop black and white negatives in D-76, Perceptol, or Technidol to a gamma that does not exceed 1.2. For close-up eyepiece projection shots where the f/ratio is 40 to 60, I use 2415 at ISO 200, developed in HC-110 with the stock solution diluted 1:30. These negatives are contrasty and sometimes difficult to enlarge. I've also had success with Ilford's XP1 400, which may be exposed at ISO 600, albeit with coarser grain than that of FP4 or Plus-X. For eyepiece projection photos in color I use Ektachrome 200 or 400, which I develop myself.

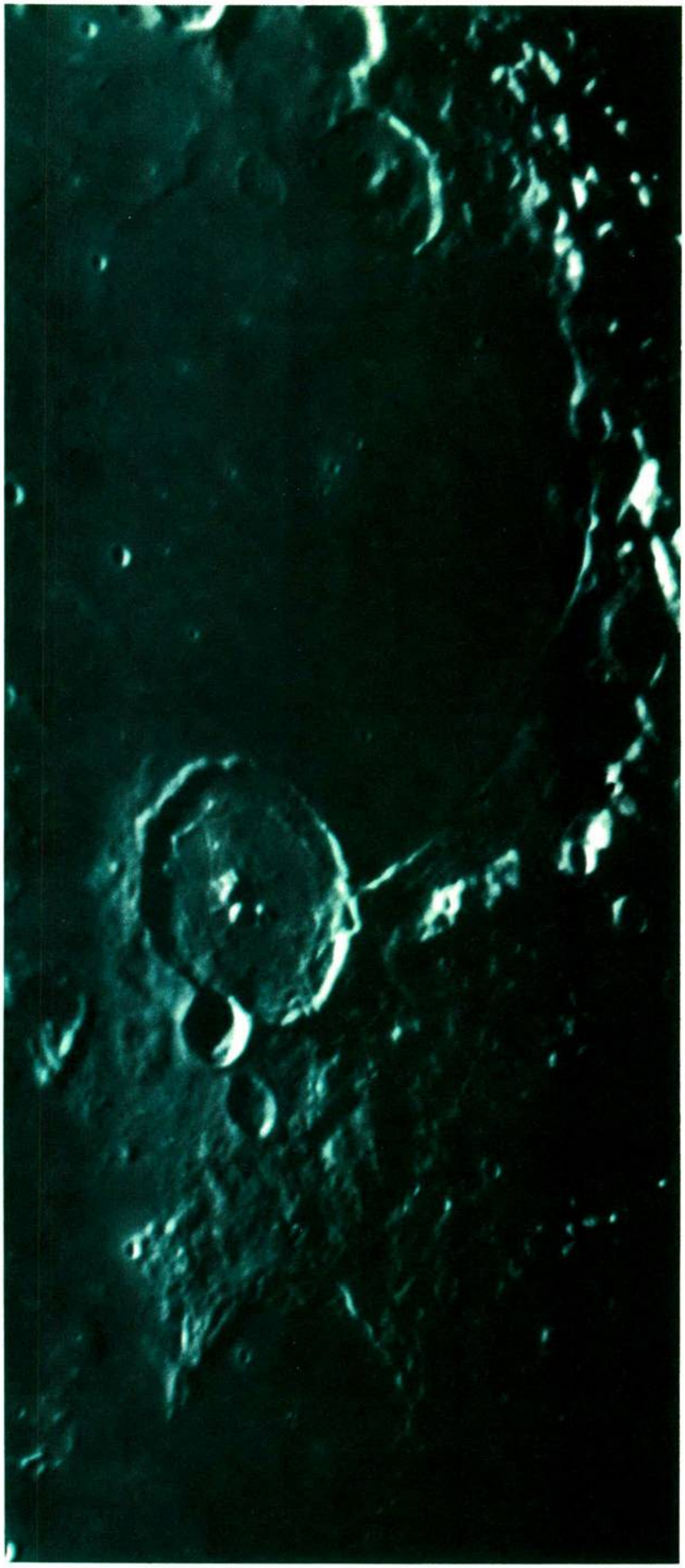
Making your own black and white prints calls for a darkroom, but is virtually essential since you can't rely on commercial photo labs to cope with astronegatives. Making good lunar prints is just a matter of paying careful attention to detail, and isn't much different than making good prints of ordinary subjects. A few tries will show which paper grade you'll need most. Well-exposed close-ups can be printed on the softer paper grades (0 to 2), whereas the whole-disk shots benefit from papers with more "snap" (grades 3 and up).

For all but the softest negatives, use grade 1 or 2 *the first time*, aiming for a print that runs from light grey to dark grey. This will look weak, but it will show everything the negative contains. You can



then work toward a final print with more contrast. Most papers are available in small packages, so it doesn't cost too much to have a wide assortment on hand. Moreover, many lunar photos are most striking when printed no bigger than about 5″ x 7″, so there's money saved there, too.

You shouldn't be satisfied with just a straight print, though some negatives will print beautifully as is. The range of brightness across lunar photos is often large, with terminator areas being quite dim by comparison with regions nearer to the sunlit limb. Accordingly you need to burn in or dodge the areas of greater or lesser negative density until you get a print that retains crisp detail all over. For burning in, use a small hole cut in a sheet of black cardboard to give extra exposure to the denser parts after you've given the main exposure for the terminator areas. Hold the card about halfway between the enlarger lens and the paper, and keep it moving constantly to blend the edges into the rest of the print.



**Mare Humorum, another flooded impact basin, is flanked by the large crater Gassendi, whose ruin is not so complete as Fracastorius'. The floor of Gassendi is cracked and knubbly with rilles and small mounds, while across the mare surface snake several wrinkle ridges. Photo taken October 9, 1981, with a 14-inch SCT at f/30, and XP1 400 film exposed for 2 seconds; south is at top.**

A common beginner's mistake is to snatch a print out of the developer when it appears to be going too dark. But short development gives the dark values a mottled and muddy quality that's instantly recognizable as amateurish. Instead, shorten the exposure time, use full development, and retain the full rich blacks that the paper is capable of.

Printing in color calls for additional equipment and raises the cost of individual prints substantially — it's not for anyone without a lot of black and white experience. Color slides, on the other hand, are easier, and many of them can be duped to give you at least some control over the brightness range and cropping. I've rephotographed lunar slides onto Ektachrome duplicating film 5076 and had good results in correcting exposure errors, modifying the framing, or dodging the terminator areas.

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*Born in Romania in 1920, Jean Dragesco moved to Paris when he was 20, where he studied optics and biology, earning a doctorate in the latter. He has been an amateur astronomer since 1936, concentrating on solar system objects. At present, he is an assistant recorder for the Jupiter section of ALPO.*

# ASTRONOMY
# Reviews

### Field Guide to the Stars and Planets

Donald H. Menzel and Jay M. Pasachoff
473 pages, hardcover, $17.95; softcover, $13.95
Houghton Mifflin (1983)

The author of a field guide on any subject faces a difficult task — that of providing the reader with whatever he or she needs to know about the subject to function well in the field, while avoiding the pitfalls of either talking down to the reader or leaving the reader behind at the first turn. In addition, any field guide ought to be easily usable in the field.

The *Field Guide to the Stars and Planets* meets the first criterion admirably. It is a clear, concise presentation of all the phenomena that confront us humans when we view the night sky, as well as an equally clear explanation of each phenomenon. Following the format developed by the late Donald Menzel for the first (1964) edition, Jay Pasachoff has completely revised the text matter in his usual fluid style. While it is in no way a substitute for a complete textbook on astronomy, Pasachoff's text is at just the right level to answer such questions as "Why does that star appear red to me, while most of the other just look white?" (See pages 108-109.)

In addition, the text is well complemented by 160 black-and-white photographs and charts, 10 Moon maps, 72 monthly sky maps, 52 atlas charts, 11 graphic timetables, 34 tables, and last, but certainly not least, 82 full-color plates. The color plates are very well selected from among the best of those produced by major observatories, NASA/JPL, and amateur astrophotographers. They are well printed and do a fine job of conveying the aesthetic aspects of astronomy.

Although I regard the *Field Guide to the Stars and Planets* as the new standard for books of this genre, it is not without its faults. My chief complaint is the small page size. All the Peterson Field Guides measure 4¼ by 7¼ inches, and I must agree that this size yields an easily handled and portable book. However, the small size also results in the excellent color plates being much less impressive than they might be if the book were, say, 8½ by 11 inches. Moreover, some illustrations are printed across the gutter, making them hard to view without breaking the spine of the book.

The chief drawback of the small page size is that the otherwise excellent sky maps and atlas charts are too small to be read easily in the field. This is the same problem that plagued the notoriously unreadable photographic atlas charts of the first edition. Now we have Wil Tirion's excellent adaptation of his well-known *Sky Atlas 2000.0* charts — certainly an improvement over the old photo charts — but they are still too small. Had the format been changed to use the 26 charts of the original *Sky Atlas 2000.0*, reduced to 8½ by 11 and printed with black stars on a white background, the book would have been more useful.

Despite the drawbacks of its small page size, the *Field Guide to the Stars and Planets* has much to recommend it. When I travel, it's the one book I take along as my "reference library" for use with my Coulter CT-100 portable telescope. I know of nothing that could replace it. *Rick Shaffer.*

### Nikon 7x50 BIF SP Binoculars

Nikon, Inc.
$749.00

They don't look really different from any other 7x50 binocular, but Nikon's new SP binocular is a top-flight performer all the way — a binocular for connoisseurs. Our "loaner" pair, serial #284789, arrived complete with sturdy carrying case, straps, attachable rubber eyecups and the usual assortment of plastic wraps and dessicant bags, just like any other binocular. One look through them showed the criticial difference: sharp, crisp, contrasty images.

Nikon's literature says that this binocular is engineered specifically for astronomical viewing. The objectives are made from low-dispersion glass and are multi-coated, the prisms are oversize and made from high-refractive index material, and the modified type-II Kellner eyepieces are optimized for good axial and lateral images. They also state that the body is fully sealed and purged against moisture and fungus.

What do you get for your $749? The SP is solidly built, well-finished gear. Look at your current binocular — do you see a hazy grey square impinging on the exit pupil? That's vignetting, lost light, due to marginal rays not being totally reflected internally in the prisms. The SPs have fully-illuminated exit pupils. There is no wobble in the eyepieces, no play between the monocular halves of the binocular.

To test their sharpness beyond the normal limitations of vision, I aimed a 7x finder telescope into the eyepiece while the SPs were pointed at the Moon. The finder magnifies the binocular's image — and any unsharpness in it. What I saw was a reasonably sharp 49x view of the Moon. I can believe Nikon's claim that the axial resolution is 3 arc-seconds. Any limitation in sharpness is, quite literally, in the eye of the beholder.

I also compared the SPs directly against my trusty Bushnell 7x50s, for example, and could see stars at least half a magnitude fainter than were visible in the Bushnells. (The Bushnells flunked the finder telescope test by giving a fuzzy, color-fringed view of the Moon.) Another observer checked his Japanese "Carl Schultz" ($35!) binoculars against the Nikon SPs on the Pleiades — and saw just about a magnitude fainter stars with the SPs. The crisp background of very faint stars added great depth to the image; it was a real pleasure to scan across winter's Milky Way starfields even from my city backyard.

Individual focus eyepieces mean it's easy to get the focus perfect for each eye, and it won't change when you don't want it to. On the other hand, not being able to refocus both eyes simultaneously would be a disadvantage for sports or bird-watching — but is not for astronomy.

If I were given $750 by an (imaginary) rich uncle to spend on the astronomical instrument of my choice, I would choose a small telescope, or a less expensive binocular with more aperture and magnification. If that same (imaginary) benefactor handed me this binocular and said, "Here, these are yours," I would be exceedingly pleased. Such a binocular is too expensive only if you haven't got its price; the SP is a fine instrument. All of us who tried them were unhappy to see them sent back. *Richard Berry.*

### Structure and Evolution of the Magellanic Clouds

S. van den Bergh and K. S. De Boer, eds.
425 pages, hardcover, $47.50; paperback, $24.75
D. Reidel (1984)

During the last 15 years, our knowledge of Nubecula Major and Minor — the Large and Small Clouds of Magellan — has greatly increased. New instruments on the ground (the 4-meter-class telescopes in Chile and Australia) as well as in space (the IUE and Einstein observatories) have precipitated this revolution in our understanding. This volume contains the proceedings from IAU Symposium 108, held in Tuebingen, West Germany in September 1983, and reviews recent progress in studying the Magellanic Clouds. It covers star formation, the interstellar medium, radio surveys, supernova remnants, and the dynamics of these small galaxies in relation to each other and the Milky Way. One section of the book is devoted entirely to the 30 Doradus Nebula and R136, perhaps the most massive single star ever observed.

### Sunset, Twilights, and Evening Skies

Aden and Marjorie Meinel
163 pages, hardcover, $29.95
Cambridge University Press (1983)

We've all seen twilight skies — but have you ever examined that golden glow for the clues it holds to Earth's atmosphere? In their new book, the Meinels — both professional astronomers at the University of Arizona — describe two decades in their search for an understanding of the subtle (and not-so-subtle) sunset, twilight, and night-sky phenomena.

I particularly enjoyed the material on the zodiacal light, zodiacal band, gegenshein, and airglow, since there is not a great deal in print about these phenomena. My own best views of these were from the island of Kauai in Hawaii, where the zodiacal band and gegenshein stood out unmistakably against the velvety blackness of the sky. That I saw them so well tends to confirm the Meinels' observation that "someone with less [than] perfect vision" (page 98) can see these broad, soft glows better than someone possessing sharp eyesight.

But the real meat of the book is Chapters 4, 6, and 7, on Earth's shadow, sunset phenomena, volcanic twilights, and twilight science. Here the authors abandon their popular style for more pithy and direct writing, which I found more attractive. Chapter 5, on volcanic eruptions, contains many fascinating quotes from the logs of ships sailing the Sunda Strait, near Krakatau, in 1883.

On the other hand, I regret the decision to print over 120 uncaptioned color photos together in a 24-page section in the middle of the book — although I am sure that it was done to keep the cost of an already expensive book within reason. Moreover, many of the photographs are too small. I found myself flipping back and forth again and again trying to find plate such-and-such, then back to the text to check what it was that I was supposed to be seeing. Such a fine collection of images deserved better treatment.

Plates 4.14 and 4.16 appear to have been interchanged, undoubtedly an error in the book's production and not at all the

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fault of the authors, and finally, plate 14.1 is "flopped" left for right. Anyone who saw Comet Ikeya-Seki will immediately recognize this error. The picture is nonetheless a striking one showing the comet in the early morning sky; in the foreground, we see an adult showing two small children that beautiful comet. Though the errors are distracting, they are certainly minor and do not detract from the book as a whole.

Despite the generally high standards, I noticed several minor errors in the text. The first is the statement on page 101 that the "dark-adapted eye is especially sensitive to light of 0.55-$\mu$ wavelength." Unless the authors do not mean to imply the peak sensitivity with the word "especially," they are wrong. The peak sensitivity of the dark-adapted (scotoptic) eye is 0.50 $\mu$; the figure quoted is the peak sensitivity for the photoptic eye.

*Sunsets, Twilights, and Evening Skies* deserves a place beside other classics of atmospheric optics, notably Marcel Minnaert's *Light and Color in the Open Air* and Robert Greenler's *Rainbows, Haloes and Glories. Richard Berry.*

### The Nearby Stars and the Stellar Luminosity Function

A.G. Davis Philip and
Arthur R. Upgren, eds.
486 pages, hardcover, $30
L. Davis Press (1983)

This volume contains the proceedings of IAU Colloquium 76, held at Wesleyan University in Connecticut in 1983. Topics discussed include the nearby stars, local kinematics and dynamics, the luminosity function, and HIPPARCOS, an astrometric satellite now being planned by the European Space Agency.

### Basic Concepts in Relativistic Astrophysics

Li Zhi Fang and Remo Ruffini
218 pages, hardcover, $33
World Scientific (1983)

This introductory textbook provides advanced physics students with a survey of relativity as it applies to modern astrophysical research.

### Supernova Remnants and Their X-Ray Emission

John Danziger and Paul Gorenstein, eds.
614 pages, hardcover, $72; paperback, $38
D. Reidel (1983)

The main purpose of IAU Symposium 101 was to present the X-ray images and high-resolution spectra of a variety of supernova remnants obtained by the Einstein Observatory. This book contains the proceedings of that symposium, which was held in Venice, Italy, in 1982.

In addition to the X-ray observations, optical, radio, and theoretical results are included. The structure and mass of young remnants, pulsars, remnants with "center-filled" morphologies (like the Crab Nebula), and evidence for enhanced elemental abundances are among the topics presented.

### Archaeoastronomy and the Roots of Science

E.C. Krupp, ed.
336 pages, hardcover, $40
Westview Press (1984)

California's first astronomers, Stonehenge, Mesoamerican astronomy, Egyptian astronomy — all are topics in this symposium volume sponsored by the American Association for the Advancement of Science. The authors, including Ed Krupp, Anthony Aveni, and John Carlson, present and interpret information left by ancient peoples who watched the stars. The book is reproduced from typescript; it includes a number of illustrations, including photographs of the Caracol of Chichen Itza, Stonehenge, the temple of Amun-Re at Karnak, and the great pyramid at Giza.

### Amateur Astronomy

Colin Ronan, ed.
256 pages, hardcover, 8.95
Newnes Books (1984)

This book originally appeared in 1979 as the *Encyclopaedia of Astronomy*. The work attempts to "explain it all," with large-format pages and many photos and diagrams, many of which are reproduced in two colors. In its revised form, *Amateur Astronomy* contains nine chapters: an introduction, motions of celestial bodies, the stars, the Sun, the solar system, the Galaxy, extragalactic astronomy, theories of the universe, and observing the universe.

### The Star Splitters

Wallace H. Tucker
182 pages, hardcover, $12
NASA (1984)

*The Star Splitters* is an account of NASA's exploration into the realm of satellite-conducted high-energy astrophysics, primarily done with the two HEAO orbiting observatories. Author Tucker provides background information on the satellites and how they work, and the types of high-energy objects the astronomers have looked at using their space-based equipment. Included is information on quasars, active galactic nuclei, pulsars, possible black hole sites, cosmic rays, stellar coronas, and supernovae.

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# A Month of Conjunctions

by Fred Schaaf

**During the Perseid shower of 1983, Douglas C. Brown caught this meteor as it passed through the northern reaches of Aquila. He used a 24mm f/2.8 lens, Tri-X film, and a 7-minute exposure.**

**To photograph Orion, Eddie Hill used a 49mm f/2.8 lens and Kodachrome 64-speed film, set his camera on a sturdy tripod, and opened the shutter for three minutes. Betelgeuse shows as light yellowish-orange; the ruddy glow of M-42 marks Orion's sword.**

## The Wanderers

Two bright planets and a prominent star arranged in a compact north-south line; a dazzling conjunction involving three bright celestial bodies. Normally such events are quite rare, but this month they occur within six days of each other. Also this month is the last Orionid meteor shower before Comet Halley, the shower's parent body, again becomes visible to backyard astronomers after more than 70 years of absence.

**Venus** shines at magnitude −3½ and is only 45 arc-minutes south of the magnitude 2.9 star Zubenelgenubi (Alpha [α] Librae) at 0h UT on the 8th; 17 hours later, Venus is 2° 27′ due south of **Saturn**, which shines at magnitude 0.7. The views on the 7th and 8th should be superb, the latter evening featuring a straight-line configuration as viewed from the Americas. Little more than 3° will contain Saturn and the close pair of Zubenelgenubi and Venus.

Venus races onward to pass about 3° north of Antares on October 27th and 1° 27′ south of **Uranus** on the American evening of October 29th (0h UT on the 28th). The planet's elongation from the Sun increases from 30° to 35° between the two conjunctions, but its altitude in mid-northern latitudes is only a few degrees higher than it was last month.

Venus passes its most southerly declination during the month; with each passing week in November and December, it rapidly gains altitude. Next February Venus will be situated almost as high as possible for northern hemisphere viewers — some 40° high at sunset. It will then be at the same azimuth as in October, but four times higher above the horizon.

Perhaps as striking as the Venus/Saturn/Zubenelgenubi encounter will be a grouping of Venus, Antares, and the Moon on the American evening of the 26th. Observers in Japan and parts of the Pacific and Central America can even witness the Moon occulting Venus around 1h UT on October 27th.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

After Saturn passes Zubenelgenubi, it will sink even lower into the evening twilight. The ringed world is more than 3° north of magnitude −0.4 Mercury on the 29th, but both planets are just 12° from the Sun and consequently invisible. What is the last day you can detect Saturn with your naked eye or with binoculars?

**Mercury** is poorly placed all month, as it falls from mid-September's greatest elongation through superior conjunction on October 10th. It either stays below or rises slightly above the horizon for the rest of the month. Mercury will be better placed next month, but won't be impressive. At a distance of 1.4 astronomical units (about 130 million miles), it is farthest from us on October 18th, at descending node on October 20th, and at perihelion on October 30th, when it lies some 0.5 AU (about 47 million miles) from Sol.

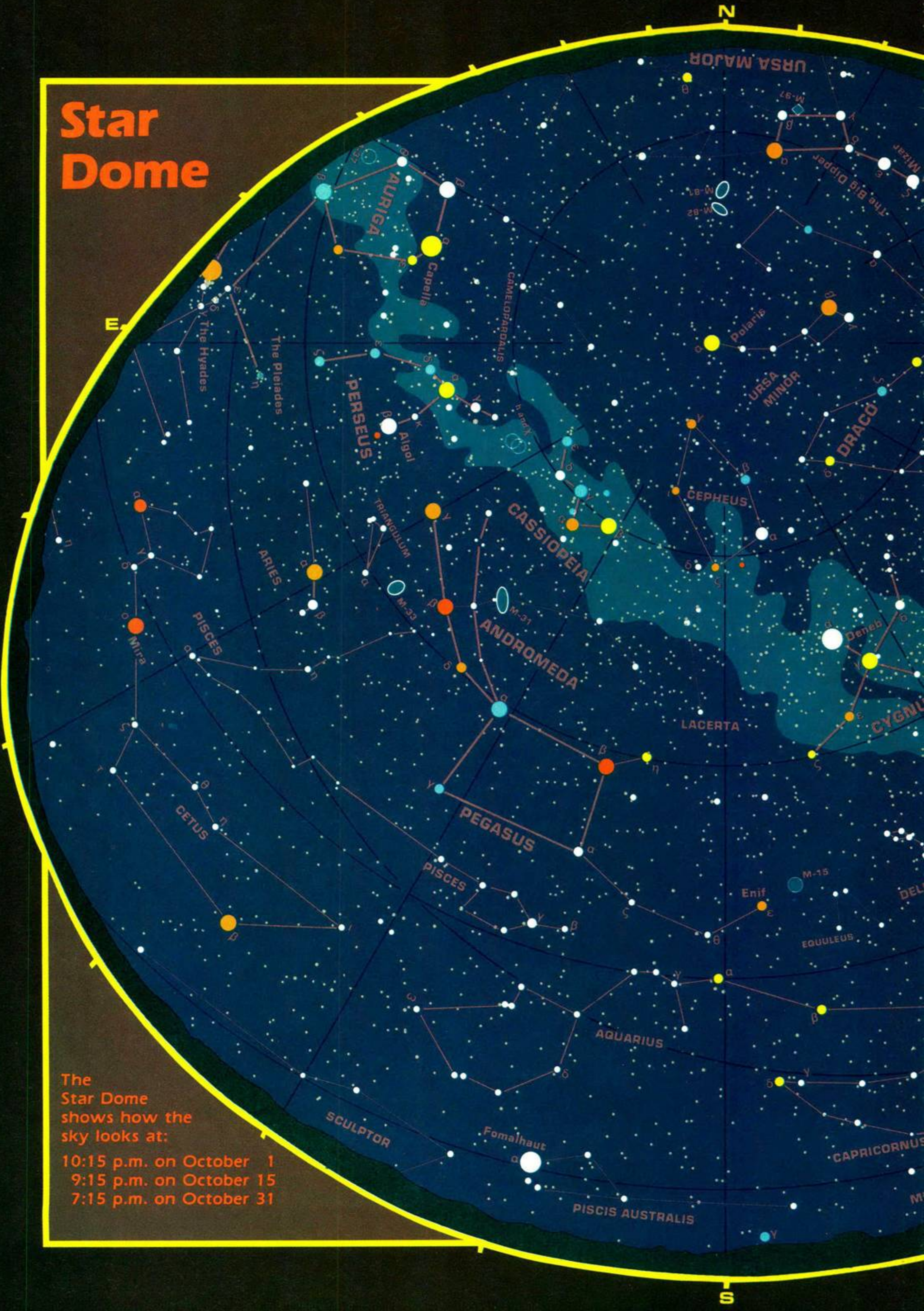
After passing more than 3° south of **Neptune** on the 3rd, bright **Mars** passes within about a degree to the south of M-8, the Lagoon Nebula. This year other conjunctions with the Lagoon have occurred, but they have been difficult to observe; this time the elongation from the Sun is about 77°, making observation easy. A bright Moon will interfere with naked-eye viewing — but binoculars should provide a good view.

On the American evening of the 18th, you may wish to gaze at Mars, when it lies about 2 arc-minutes south of a 5.8 magnitude star. Ten days later it will be the same distance south of a star of 6.2 magnitude.

This event pales when compared with the conjunction between Mars, Jupiter and Lambda (λ) Sagittarii that takes place on the 14th. Mars catches magnitude −2 Jupiter within an hour of the time Jupiter is 2° due north of λ Sgr. At 0h UT on the 14th, Mars is just 5 arc-minutes north of λ Sgr. Coincidentally, λ Sgr shines with about the same intensity as Zubenelgenubi.

Since Mars and **Jupiter** are moving slower in their paths than Venus, the three stay together for some time — at closest

# Star Dome


N
E
S
URSA MAJOR
M-97
The Big Dipper
Mizar
M-81
M-82
AURIGA
M-37
Capella
CAMELOPARDALIS
Polaris
URSA MINOR
DRACO
The Hyades
The Pleiades
PERSEUS
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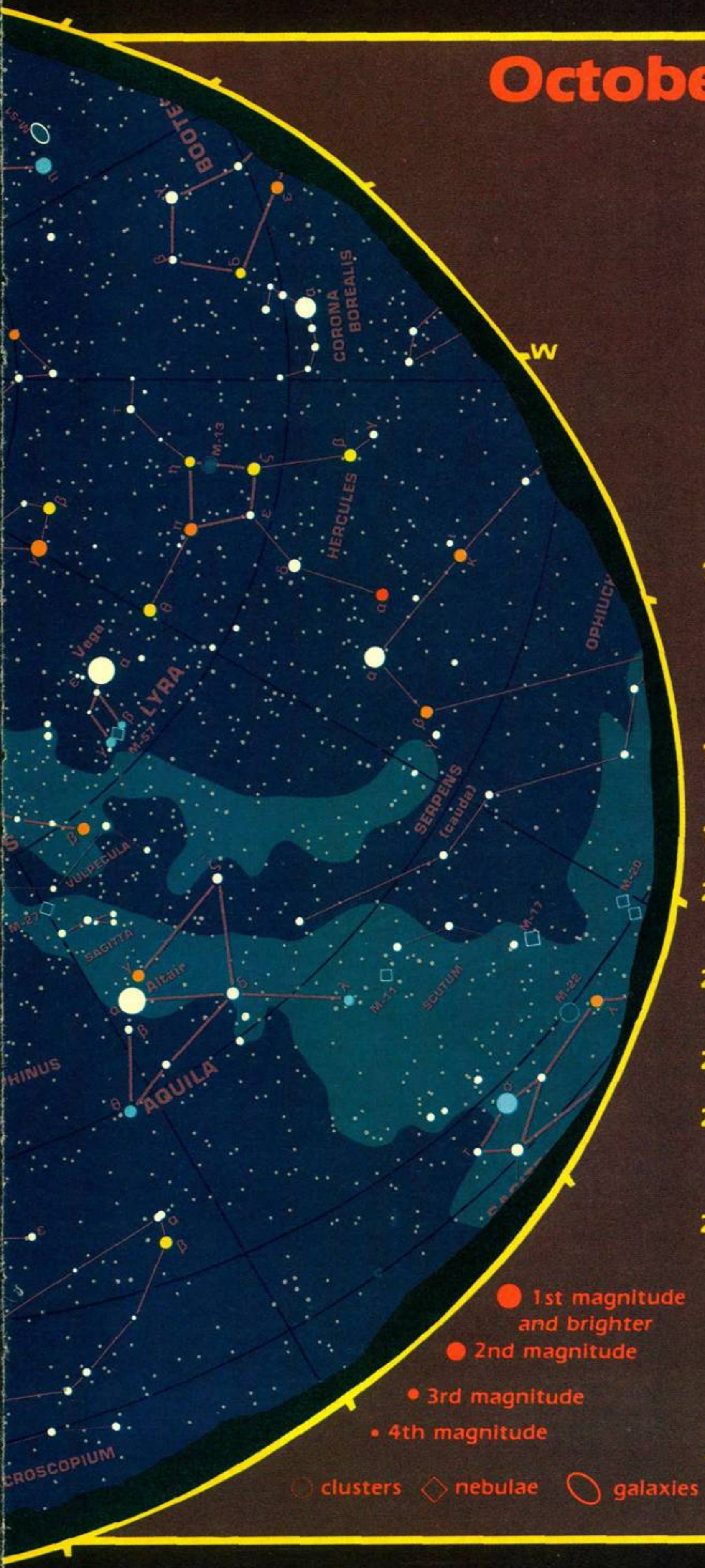
CEPHEUS
CASSIOPEIA
TRIANGULUM
ARIES
M-33
M-31
ANDROMEDA
Deneb
CYGNUS
Mira
PISCES
LACERTA
CETUS
PEGASUS
PISCES
M-15
Enif
DELPHINUS
EQUULEUS
AQUARIUS
SCULPTOR
Fomalhaut
CAPRICORNUS
PISCIS AUSTRALIS

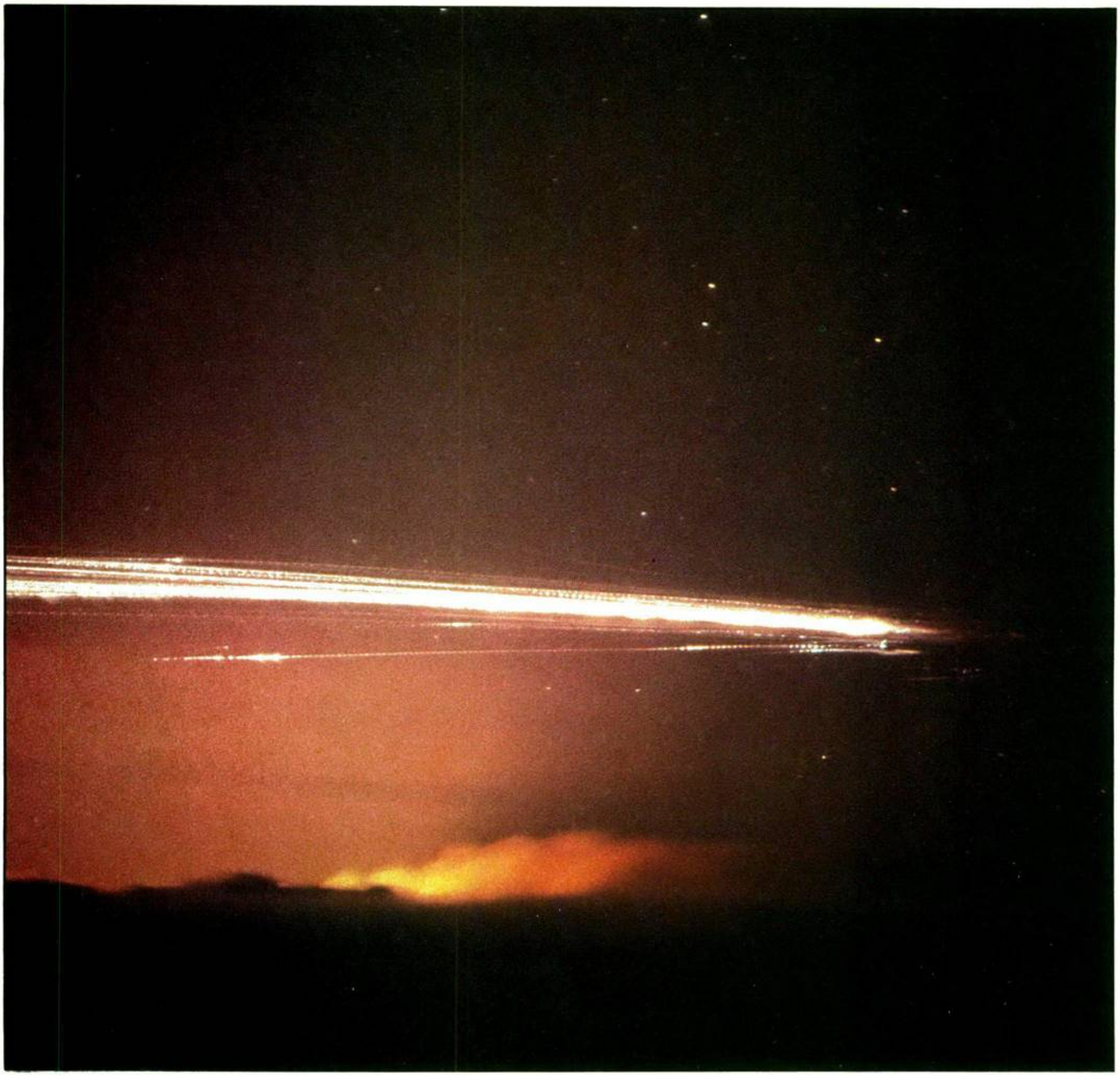
The Star Dome shows how the sky looks at:

10:15 p.m. on October 1
9:15 p.m. on October 15
7:15 p.m. on October 31

# October Sky Almanac

| | |
|---|---|
| **1st** | First Quarter Moon occurs at 5:52 p.m. EDT. Also, tonight the Moon will lie near Mars and Jupiter. |
| **8th** | The Moon is farthest from Earth at 10:45 a.m. EDT: 252,472 miles. Tonight, Venus will lie about 3° south of Saturn in the evening sky. |
| **9th** | The Moon is Full at 7:58 p.m. EDT. The predawn hours today are the best time to look for meteors in the annual Draconid shower. |
| **10th** | Mercury is at superior conjunction with the Sun and moves into the evening sky. (You probably won't be able to spot it there until the middle of November, however.) |
| **13th** | Tonight, Mars will lie less than two degrees south of Jupiter. |
| **17th** | Last Quarter Moon occurs at 5:14 p.m. EDT. |
| **20th** | The predawn hours today are the best time to observe the annual Orionid meteors. |
| **23rd** | The Moon is closest to Earth at 9:50 a.m. EDT: 222,766 miles. |
| **24th** | The Moon is New at 8:08 a.m. EDT. |
| **26th** | A thin crescent Moon will lie near the bright planet Venus and the star Antares in the evening sky tonight. |
| **28th** | Daylight Saving Time ends; turn clocks back one hour. Also, tonight and tomorrow, the Moon will be passing near the bright planets Jupiter (tonight) and Mars (tomorrow). Look for them low in the southwest soon after sunset. |
| **31st** | First Quarter Moon is at 8:07 a.m. EST. |


BOOTES
CORONA BOREALIS
W
HERCULES
M-13
OPHIUCHUS
Vega
LYRA
M-57
SERPENS (cauda)
VULPECULA
M-27
SAGITTA
M-20
M-17
Altair
M-11
SCUTUM
M-22
PHINUS
AQUILA
CROSCOPIUM
● 1st magnitude and brighter
● 2nd magnitude
• 3rd magnitude
• 4th magnitude
○ clusters ◇ nebulae ⬭ galaxies



From Hale Pohaku, Hawaii, William B. Albrecht captured the Space Shuttle *Challenger*'s main fuel tank as it vaporized while re-entering the atmosphere. On the ground, fire and lava flow from Mauna Loa, one of the few active volcanoes near heavily populated areas.

spanning just 2°. Mars lies farthest south of the ecliptic on October 12th, just two days before the conjunction.

There are two First Quarter **Moons** this month; unfortunately, the Moon will hinder observing the **Orionid** meteor shower. These meteors, thought to be debris of Halley's Comet, are due to reach their peak on the 20th — when the Moon is three days past Last Quarter. Despite the Moon, however, you may see quite a few Orionids during the second half of October.

## The Starry Sky

Contrary to popular notion, not all of the *autumn* constellations are dim. In fact, autumn is the best season to look *north* for rich Milky Way starfields.

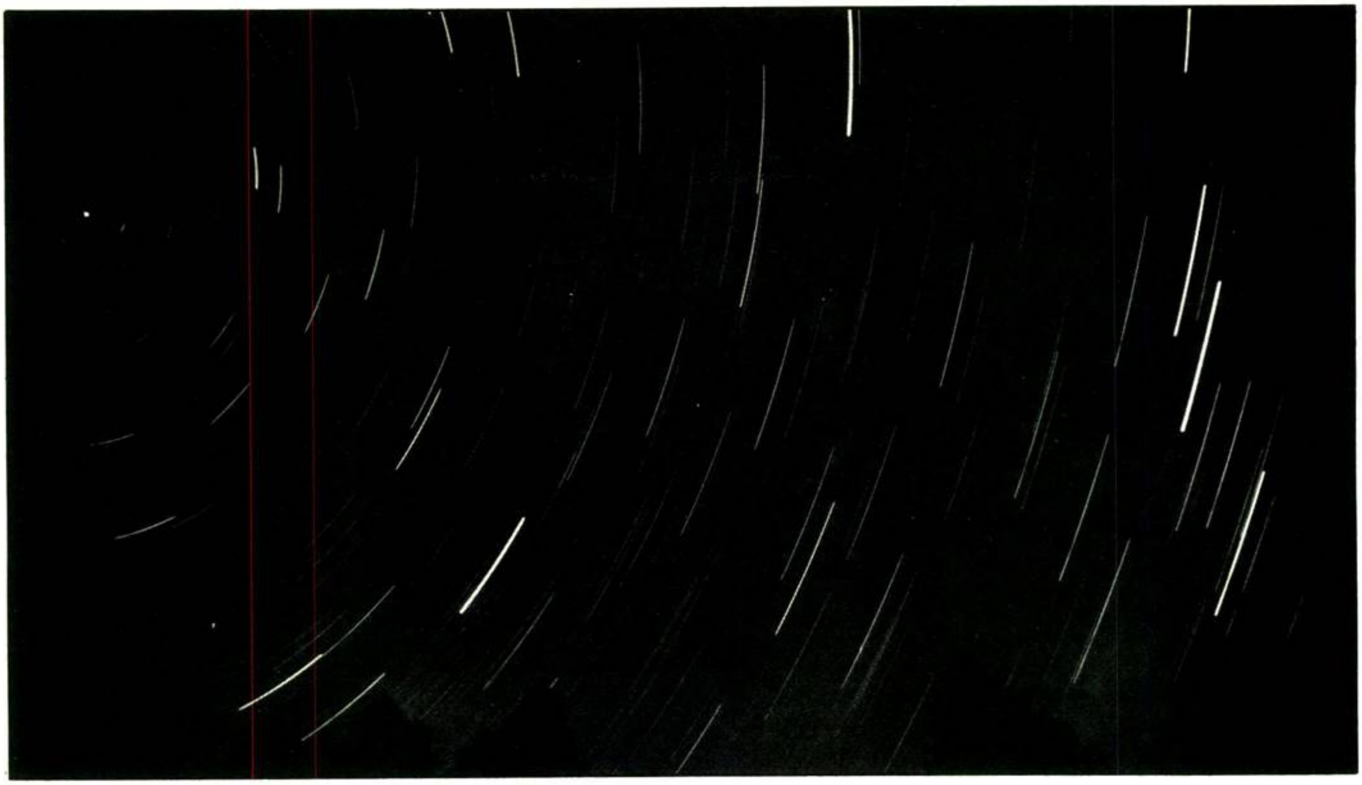
As seen from the United States, **Cygnus** is just north of the zenith on October evenings, with **Deneb** following the more westerly **Vega** in **Lyra** and the far more southerly **Altair** in **Aquila**. But Cygnus is a summer star group: high in the northeast is a true autumnal constellation whose main pattern is more condensed than Cygnus. During October evenings the bright W of **Cassiopeia** the Queen is inverted to an M, but is still easily recognizable.

The five brightest stars in Cassiopeia all shine at magnitudes 2 or 3. **Gamma** (γ) **Cassiopeiae** averages 2.3 but has risen to 1.6 on at least one occasion. There are many beautiful clusters around Cassiopeia's main figure, and some of them can be detected with binoculars.

The most spectacular cluster, or rather pair of clusters, in this region — the **Double Cluster in Perseus** — can be found by scanning between the main patterns of Cassiopeia and Perseus. These clusters are naked-eye objects in a reasonably dark sky. They are less fuzzy and more lovely in binoculars.

Perseus is a bright constellation placed high up after midnight during October for observers at 40° north latitude. Earlier in the evening Perseus is still fairly low in the northeast, with the first-magnitude stars **Capella** and **Aldebaran** lying closer to the northwestern horizon.

Although Capella and Aldebaran do not reach the meridian until about 3 a.m. to 4 a.m. local time in October, they are



**Brian Skiff made this exposure with a 15mm f/2.8 lens and 400-speed film; it shows a wide swath of sky, containing Spica, Saturn, Mars, and Antares at right. The unguided exposure lasted 58 minutes.**

already almost as high above the horizon as the southerly **Fomalhaut** ever gets. October is the month when Fomalhaut, the mouth of **Piscis Austrinus**, the Southern Fish, culminates in mid-evening. Fomalhaut is the sole first-magnitude star of the traditional autumn constellations. Made up of dimmer stars but also visible is **Pegasus**, whose **Great Square** we will examine in November, when it sits squarely on the meridian around 9 p.m. local time.

Just west of Cassiopeia is the often neglected constellation **Cepheus** the King. The brightest star in Cepheus is **Alderamin**, Alpha Cephei. Dimmer but still conspicuous is Gamma Cephei, known as **Errai**, which is closer to the north celestial pole and **Polaris** than any other bright star except the two "Guardians of the Pole" in the **Little Dipper** itself. On a star atlas you can also find **Delta** (δ) **Cephei** (the prototype Cepheid variable star) and **Mu** (μ) **Cephei**, Herschel's Garnet Star, which looks ruddy orange in binoculars.

Between Piscis Austrinus and Pegasus, **Aquarius** the Water-Bearer is composed of lines of stars like fingers of a widely extended hand. The center of the constellation is the faint asterism called the Urn, or **Water Jar**, which lies on the celestial equator. One hour east in right ascension lies a larger asterism, the **Circlet** — the western half of **Pisces** the Fish.

Follow several faint stars in a line almost due east from the Circlet and you will come to Alrisha — the "knot" in the rope which connects the two fish by their tails. Identifying the stars of the second, more northerly fish can be difficult even with dark skies. The stars form a line parallel to one between Alrisha and Beta (β) Andromedae.

## Skylore

Legend says Aquarius is the Water-Bearer. But who is this water-bearer? Different answers come from different cultures. We'll concentrate on the ones from Mesopotamia and India before the year 1000 B.C.

Picturing these stars as a man pouring water is a widespread idea among the ancients. Perhaps the explanation lies in a watery coincidence affecting two of the influential nations at the dawn of civilization — Egypt and Mesopotamia.

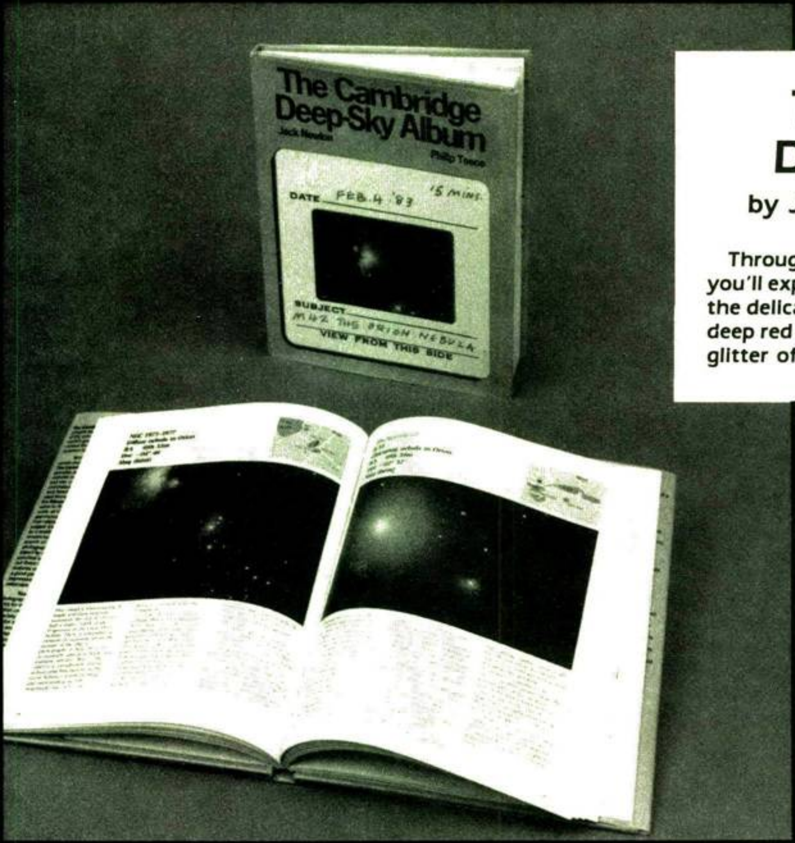
Mesopotamia means "between the rivers" — the rivers being the Tigris and the Euphrates. Here, as in Egypt, the rainy season came during the 11th month of a year beginning with the March equinox — around our January. The Babylonians called this time Shabatu, the Curse of Rain. During this time the Sun lay in Aquarius, causing the Babylonians to call Aquarius Gu, meaning an overflowing water jar. The Akkadians called it Ku-ur-ku, the seat of the flowing waters. And at one time in the region Aquarius represented Ramman or Rammanu, a storm god who poured water from a vase.

A great god among Mesopotamians was Ea, which may be connected with both Aquarius and Capricornus. The Babylonians sometimes pictured Aquarius as Kulilu, a destructive half-fish, half-man, created by monsters. Ea was venerated most by the Sumerians, the rulers of Mesopotamia who preceded the Babylonians, but Ea and many of the figures of Sumerian mythology were adopted by Babylonians. Four or five thousand years ago, civilized people in Mesopotamia may have pictured their god in the stars of Capricornus and an evil, stormy monster in the nearby Aquarius.

To the ancient Hindus, Aquarius was the wise sky-god Varuna, who rode on the stars of Capricornus, which represented a sea monster called the *makara*. This myth has little or no relation to those of the Sumerians, because Varuna and his Hindu worshipers evolved largely from Indo-Aryan people who invaded India around 1600 B.C. The Indo-Aryans were the easternmost members of the Indo-European peoples.

These Indo-Europeans favored a triad of gods to be their chief deities — in India and the near east they were Mithra, Indra, and Varuna. The word Varuna is etymologically related to the Latin Uranus (Greek Ouranos), the grandfather of Jupiter (Zeus), who was also a mighty sky-god. In Hindu mythology, Varuna was linked with the Moon (which was thought to be a repository of the ambrosial drink *soma*) and was pictured as a white man with a snare (rope and noose), an emblem of his role as universal judge.

What god did the Egyptians relate to Aquarius? Next month we will look at how an Egyptian god may have entered Greek myth. And we will discuss the Greek account of the Great Flood.



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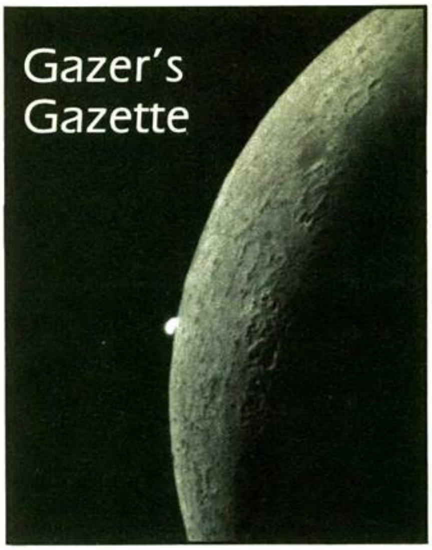
# Chasing Moon Shadows

by
**David Dunham & Donald Stockbauer**



Boris Starosta

In the early evening of May 9th, 1981, several amateur astronomers in the Washington D.C. area nervously eyed low clouds filling the sky as they loaded telescopes and tape recorders into their cars. Forecasters at the National Weather Service said a band of clear sky over northeastern Maryland would probably hold for a few hours, in spite of a cold front moving in across the Appalachians.

The observers rendezvoused with others in Darlington, Maryland. From there, they fanned out into the rural countryside, each seeking their appointed road intersection or landmark. Soon the monotonous TOCK! TOCK! TOCK! of time signals from radio station WWV filled the air as the observers watched the dark northern edge of the Moon approach the fourth-magnitude star Delta Cancri.

Tape recorders caught the excited calls of "disappearance!" and "reappearance!" along with WWV's signals as mountains near the lunar north pole successively covered and uncovered the star. At one location, Alan Fiala from the U.S. Naval Observatory videotaped the graze using a low-light television camera attached to an 8-inch Schmidt-Cassegrain telescope — a "first" in on-site occultation observing.

To record different depths of the graze, the stations straddled the predicted graze path at intervals of about a tenth of mile. After the event, collating the observers' positions and timings allowed astronomers to calculate a detailed profile of the edge of the Moon. Profiles such as this are used in conjunction with solar eclipse timings to determine, among other things, small but climatically significant variations in the Sun's diameter.

### What Makes an Occultation?

As the Moon orbits the Earth, it eclipses stars in its path. These events are called "occultations," a term derived from the Latin verb "to cover." At most, an occultation can last a little more than an hour, the time needed for the Moon to move through its own diameter, 2160 miles. But most occultations don't last this long, as the Moon seldom passes centrally over the star. A few occultations are visible with a moderate-size telescope any night it's clear and the Moon is up.

Astronomers distinguish total occultations from their rarer cousins, the grazing and partial kinds. At the northern and southern limits of visibility for an occultation, the apparent path of the star is a line just touching the lunar disk. Since the Moon isn't a perfect sphere, the star may disappear and reappear repeatedly as mountains along the lunar limb block its light. This grazing occultation is visible only within a narrow band, generally two or three miles wide — the size of the mountains and valleys near the lunar poles.

During a graze, observers often see "blinks" and "flashes" as well as simple disappearances and reappearances. In a "blink," the star's light blinks out and turns on again immediately as the top of a lunar hill briefly covers it. A star can also flash into view as it crosses a deep lunar valley — you see an appearance followed so quickly by a disappearance that the two events cannot be timed separately. If the graze involves a planet, the view is unusually spectacular since the planet will be covered only partially. These exciting and dramatic events are visible over a graze zone whose width in miles is roughly equal to the diameter of the planet in arc-seconds.

Although most total occultations are startlingly sudden, you can sometimes see a star disappear or reappear in two quick but distinct steps. This indicates the star is a close binary pair. In fact, for resolving double stars, occultations fill an observational gap between direct visual and spectroscopic observations. The geometry of occultation observations often affords a resolution of 0.01 arc-second, and high-speed automatic recording of occultations can give still better resolution — enough even to allow astronomers to measure the angular diameters of some stars.

### Observing Occultations Visually

Many observers are content simply to watch whatever occultations come their way, enjoying these attractive celestial events for what they are. Others take a more direct approach, seeking out occultations and banding together into groups to observe them. Like meteor watching, occultation observing tends to be a social activity — even if you're clouded out, you've had a chance to get together with other astronomy friends. But besides the fun of an expedition, occultations also offer solid scientific value.

Timing an occultation is quite simple: you start a stopwatch as soon as the star disappears or reappears. Then you listen to the time signals, noting at which tenth of a second on the watch the second-beeps occur. (This is a lot easier to do with a stopwatch having a 10-second full sweep.) You stop the watch at the next minute beep. This does not have to be done precisely, since you read only the whole seconds from the stopwatch, the tenths having already been estimated. You then subtract the elapsed time on the watch (plus your estimated tenth of a second) from the minute to obtain the raw time of the occultation. Lastly, from this you subtract your reaction time to get the actual time of the occultation.

Disappearance reaction times for most people run 0.3 to 0.5 second. Under more difficult conditions, such as fainter stars, haze, or reappearances, reaction times can be as long as a full second or more. After timing a few events, you'll develop a pretty good sense of how you react. Some astronomy clubs have artificial stars with timing devices to measure individual reaction times. If you don't have access to such equipment, you can estimate your reaction time with a digital watch or stopwatch. Cover most of the face of an analog stopwatch, start it, and then stop it as soon as you see the sweephand appear in the hole. With a digital watch in stopwatch mode, cover the unit seconds display and stop it as soon as you see the "0" change to "1" in the tens position. Make several trials and take an average.

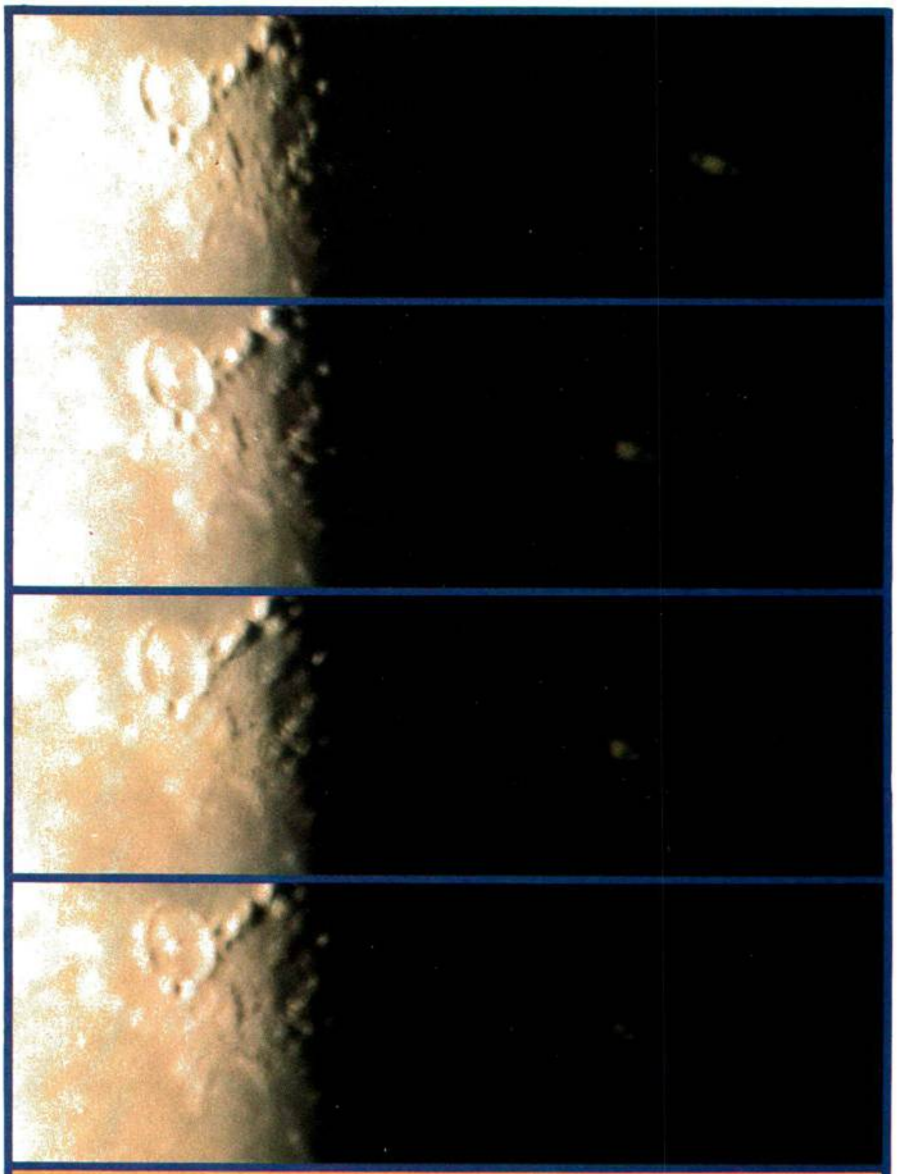
When you are observing, don't try to "cancel" your reaction time by stopping the watch at the minute-beep; the reaction time won't be the same since the second-beats produce a rhythm very hard not to anticipate. Also, audio and visual reaction times can differ. You can largely avoid the reaction time business by listening to the time signals and counting the second-beeps, then mentally estimating the tenth of a second when the occultation occurred. This "eye-and-ear" method requires considerable concentration and practice, but eliminates the need for a stopwatch.

Time signals should be picked up with a short-wave receiver. WWV in Colorado (and WWVH in Hawaii) broadcast at exactly 2.5, 5, 10, 15, and 20 MHz; you can pick up WWV most of the time throughout North America. The Timekube receiver sold by Radio Shack is easy to use, since you don't have to tune it. Fresh batteries and a long wire antenna suspended above the ground will improve the reception of any short-wave receiver. If you do not have a short-wave radio, accurate time signals are available from the U.S. Naval Observatory by telephoning (900) 410-8463. (U.S.N.O. time is also available in the Washington D.C. local area at 653-1800.) Most local phone company times are not accurate — exceptions are New York City and Chicago.

These timing methods work well for total occultations, but are inadequate for grazes, where several events can occur during a single minute. The easiest way to time grazes is that used by the observers at the Delta Cancri event: tape-record WWV and voice calls together. Small battery-powered recorders are ideal, but be sure you have sufficient tape to record the graze, which can last many minutes. Don't start to record too early! In cold weather, the recorder batteries will lose power, so keep them warm by putting the recorder under your jacket. Test beforehand to be sure that both the time signals and your voice record clearly.

Buzzers or clickers might be more accurate than voice calls, but the timing accuracy needed for grazes, 1.0 second or better, is not as stringent as that for total occultations — and besides, it's helpful to know just what the particular event was. Large expeditions tend to have more tape recorders than short-wave receivers, so use a standard-broadcast AM station as a secondary time standard. All observers without short-wave receivers record the AM station with their event calls. One observer (or someone in town not even on the expedition) records WWV *and* the AM station, creating a master tape that can time any syllable or word in the AM broadcast.

After the graze, replay the tape, counting second-beeps from zero at the minute mark to get the whole seconds for each event. Then replay using a stopwatch to determine the tenths. Tape recorders aren't just for grazes, though — they are also helpful at total occultations, especially if the star is double and disappears or reappears in steps. They are useful for asteroid occultations, too, where the star often reappears only a few seconds after it disappears.



**On June 10th, 1984, the Moon occulted Saturn as seen from the South Pacific. This dramatic sequence shows Saturn disappearing behind the dark limb of the Moon. Photo by Noel Munford of Palmerston North, New Zealand, who used a 12-inch Newtonian at f/69, Fuji HR200 film, and ¼-second exposures.**

We've said a lot so far about equipment and procedures, but nothing about the "heart of the matter" — your telescope. The reason for this is that basically any telescope you'd use for ordinary observations will do, as long as it will show the star to be occulted. Observing procedures with a clock-driven equatorial are easy: set up, polar-align, and start tracking on the star with a medium-power eyepiece.

But even alt-azimuth scopes such as Dobsonians perform well if you use low to moderate eyepiece magnifications. For total occultations, you'll learn to judge how fast the Moon's limb is approaching so that the star is roughly centered in the field of view when it disappears. For reappearances, look in your predictions to see when the event occurs and to find the position angle on the lunar disk where it is scheduled to reappear. Grazes last longer, and you'll have to recenter the star in the field of view several times, perhaps missing one or more of the phenomena in the process.

Events that occur on the Moon's bright limb are trickier to time, since a dim star can blend into the lunar terrain. Use as high a power as you can, but don't make it so high that bad seeing effects dominate the view. Dark limb events are wonderful: reappearances are very quick — you peer anxiously into the eyepiece, seeing an Earth-lit Moon, but nothing more. There's nothing — nothing — then bingo! it's there! On a disappearance, at first you think the Moon will *never* reach the star. Then, abruptly, it looks quite close and you tell yourself it'll be only a few seconds more. Nervously, you adjust the scope's aim. Closer — closer — then, it's — gone!

With planets, the thrill is even greater, in part because the events are comparatively rare and in part because planets have disks with detail. Watching Saturn, say, dip in and out of view behind lunar mountains is something you'll probably see only a few times in a lifetime of observing — and will certainly never forget. Even total occultations of planets are delightful: Jupiter, for example, emerges from behind the Moon, heralded (as any king of the gods ought to be) by his stately retinue of satellites.

### Occultation Predictions

The annual *Observer's Handbook* of the Royal Astronomical Society of Canada includes an occultation supplement containing predictions for 18 American and Canadian "standard stations," each of which has about 15 events for stars to fifth magnitude. It also tells how to compute approximate times for locations within about 200 miles of each station. The supplement also contains maps showing the northern and southern limits of over 100 occultations; favorable grazes are visible within about two miles of these lines.

Look for the *Observer's Handbook* in your library — or better yet, order it for $8.00 (U.S.) from the Royal Astronomical Society of Canada, 136 Dupont St., Toronto, Ontario, Canada M5R 1V2. An offprint of the supplement is also available from the RASC for 50 cents and a long self-addressed unstamped envelope. These predictions are prepared by the International Lunar Occultation Centre (ILOC) in Tokyo, Japan. ILOC also distributes standard observation report forms and collects all lunar occultation observations for analysis.

More extensive predictions can be obtained by sending accurate geographic coordinates and a long self-addressed stamped envelope to Walter V. Morgan, 10961 Morgan Territory Rd., Livermore, CA 94550. Similar predictions for Europe are available from Hans Bode, Bartold-Knaust-Strasse 8, D-3000 Hannover, West Germany. You can get accurate coordinates for your observing site from topographic maps — try the public library or a local map dealer. You can also order them by mail from the U.S. Geological Survey, Distribution Branch, 1200 S. Eads St., Arlington, VA 22202 (for the U.S. east of the Mississippi River, including all of Louisiana and Minnesota) or from U.S. Geological Survey, Denver Federal Center, Bldg. 41, Denver, CO 80225 (U.S. west of the Mississippi). For Canadian locations, write to Canada Map Office, 615 Booth St., Ottawa, Ontario K1A 0E9.

### Grazing Occultations and IOTA

During the last months of 1984, several very favorable grazing occultations occur near the predicted limits shown on the map on these pages. Some of these pass near or across large cities. Contact the organizers, whose addresses and telephone numbers are listed in the table below if you want to join one of these graze expeditions. If you do not live near one of these cities, write to the International Occultation Timing Association (IOTA), P.O. Box 3392, Columbus, OH 43210-0392. IOTA will put you in touch with the member who lives closest to you, or provide information so you can mount your own expedition.

Detailed computer predictions (lists of geographical coordinates in the northern or southern occultation limit and predicted lunar profile) of grazing occultations are available for $1.50 each from IOTA. Alternately, you can join IOTA for $11 ($16 if you don't live in the U.S., Canada, or Mexico). Membership benefits include free graze predictions, papers describing use of the graze predictions, and a subscription to *Occultation Newsletter* (also available separately for $5.50 in North America).

Graze predictions are computed for specified distances from your station and include stars brighter than magnitude 8.6. Each year, within about 100 miles of any given location, there are about two dozen grazes potentially visible with a 6-inch telescope. If you've ever wondered what all the "occultation fuss" was about, now's a perfect time for you to join in the fun!

---

*David Dunham and Donald Stockbauer direct the grazing occultation prediction and observation collection efforts of the International Occultation Timing Association.*

## Grazing Occultation Expedition Organizers

| | | |
|---|---|---|
| Gerald Rattley | 5 S. Pueblo St., Gilbert, AZ 85234 | (602) 892-5698 |
| Derald Nye | Rt. 7, Box 511, Tucson, AZ 85706 | (602) 762-5504 |
| Robert Lozano | 1415 Michigan, Santa Monica, CA 90404 | (213) 450-1944 |
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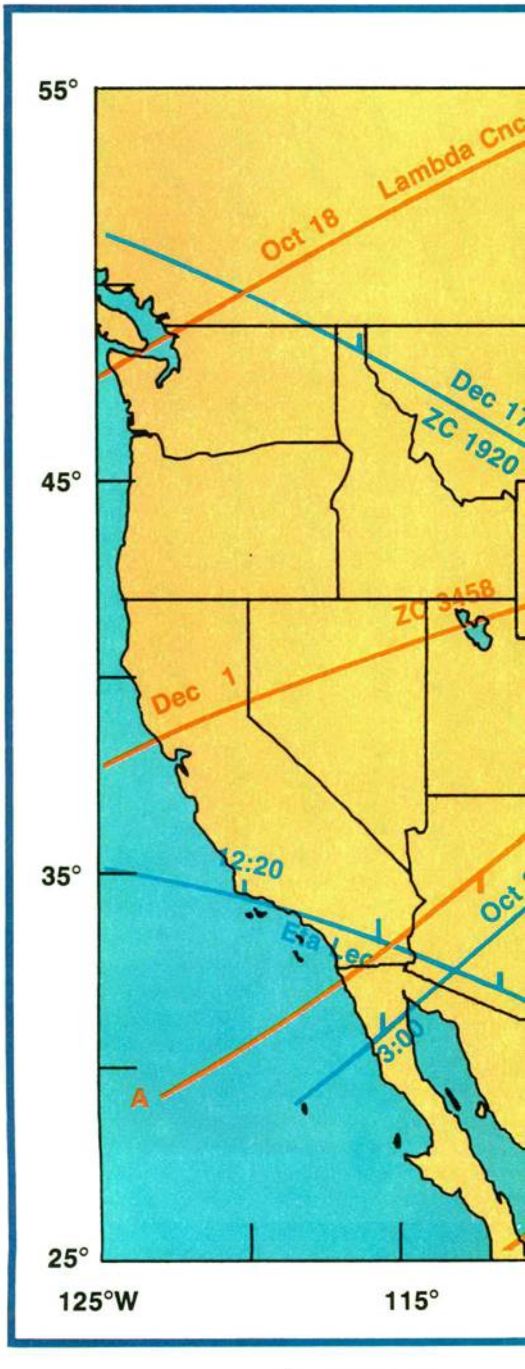
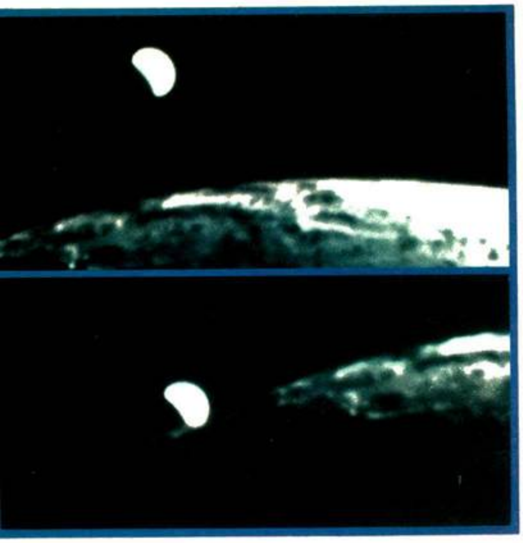
**Right: On the morning after Christmas, 1978, many people in eastern and central North America watched the Moon occult Venus. In two photos taken five minutes apart, Tom Koed of North Little Rock, Arkansas, captured the exciting event. He used an 8-inch SCT at f/100, Tri-X film, and 2-second exposures during very bad seeing. The map below shows the grazing occultation paths for the rest of the year across the U.S., southern Canada, and northern Mexico. Occultations are total to the south of a red line and north of a blue one; the tick marks are at 10-minute intervals. In the track for October 1st, the solid part indicates where the graze occurs on the Moon's dark limb; the dotted part where it occurs on the bright limb. An "A" at one end of a track signifies that the object's altitude is too low, and "S" means that sunlight interferes. Map and data from the authors.**

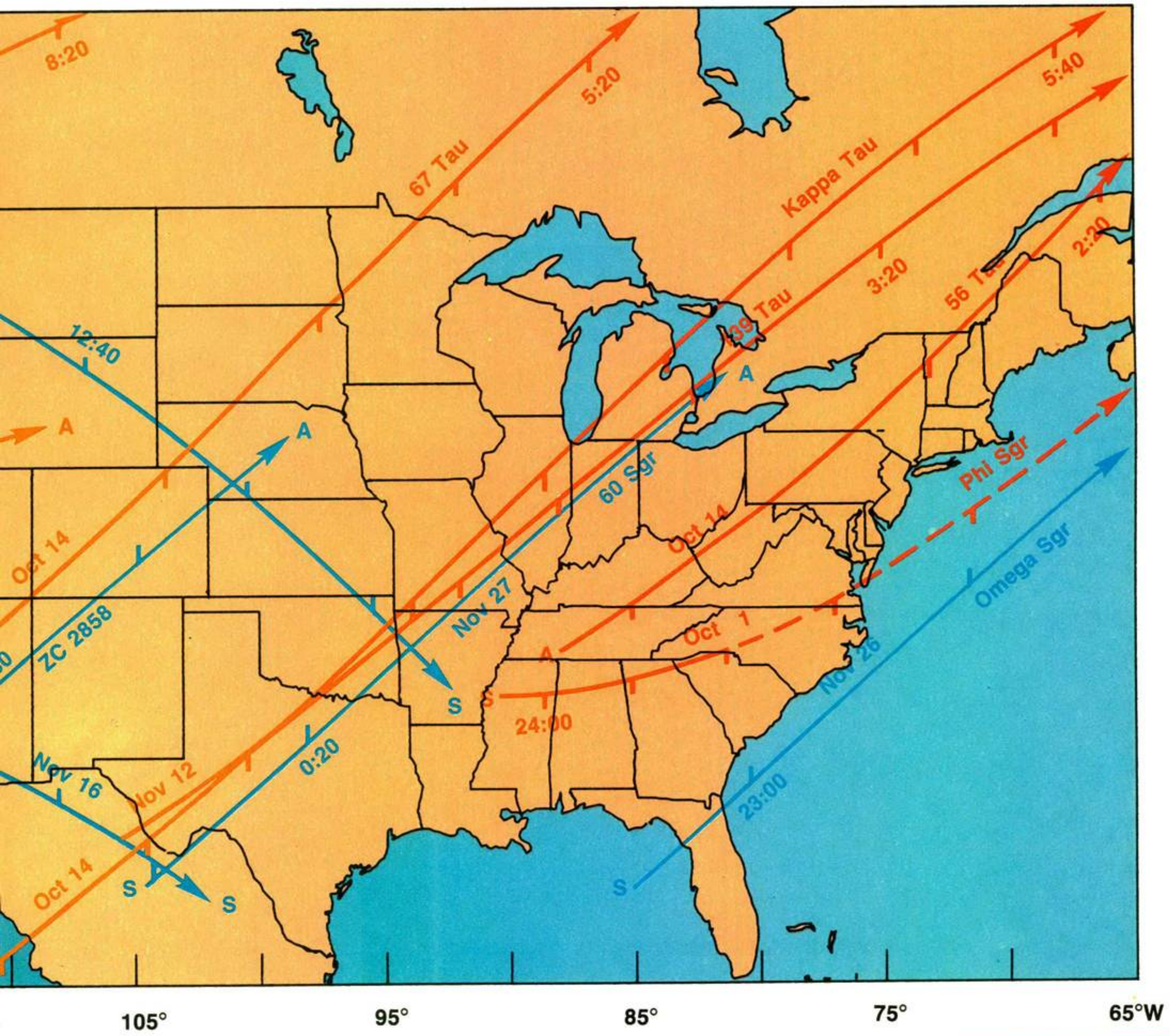




## Favorable Grazing Occultations During Late 1984

| Date | Star | Mag. | % Sunlit | U.T. |
|---|---|---|---|---|
| Oct. 1 | Phi Sagittarii* | 3.3 | 51 waxing | 23:55 |
| Oct. 14 | 56 Tauri | 5.3 | 85 waning | 1:59 |
| Oct. 14 | Kappa Tauri* | 4.4 | 84 waning | 4:29 |
| Oct. 14 | 67 Tauri | 5.4 | 84 waning | 4:34 |
| Oct. 18 | Lambda Cancri | 5.9 | 45 waning | 8:11 |
| Oct. 30 | ZC 2848* | 5.5 | 35 waxing | 2:44 |
| Nov. 12 | 139 Tauri | 4.9 | 89 waning | 2:53 |
| Nov. 16 | Eta Leonis* | 3.6 | 47 waning | 12:10 |
| Nov. 26 | Omega Sagittarii | 4.8 | 18 waxing | 22:52 |
| Nov. 27 | 60 Sagittarii* | 5.0 | 19 waxing | 0:10 |
| Dec. 1 | ZC 3458 | 6.5 | 58 waxing | 7:00 |
| Dec. 17 | ZC 1920 | 6.7 | 29 waning | 12:24 |

*Close double star; the U.T. column gives the Universal Time of the event at the westernmost (earliest) end of the graze path.


8:20
5:20
67 Tau
5:40
Kappa Tau
3:20
56 T
2:20
139 Tau
12:40
A
A
A
A
60 Sgr
Phi Sgr
Oct 14
Oct 14
Oct 14
ZC 2858
Nov 27
Oct 1
Omega Sgr
Nov 26
S
S
S
S
S
24:00
0:20
Nov 16
Nov 12
23:00
105°
95°
85°
75°
65°W

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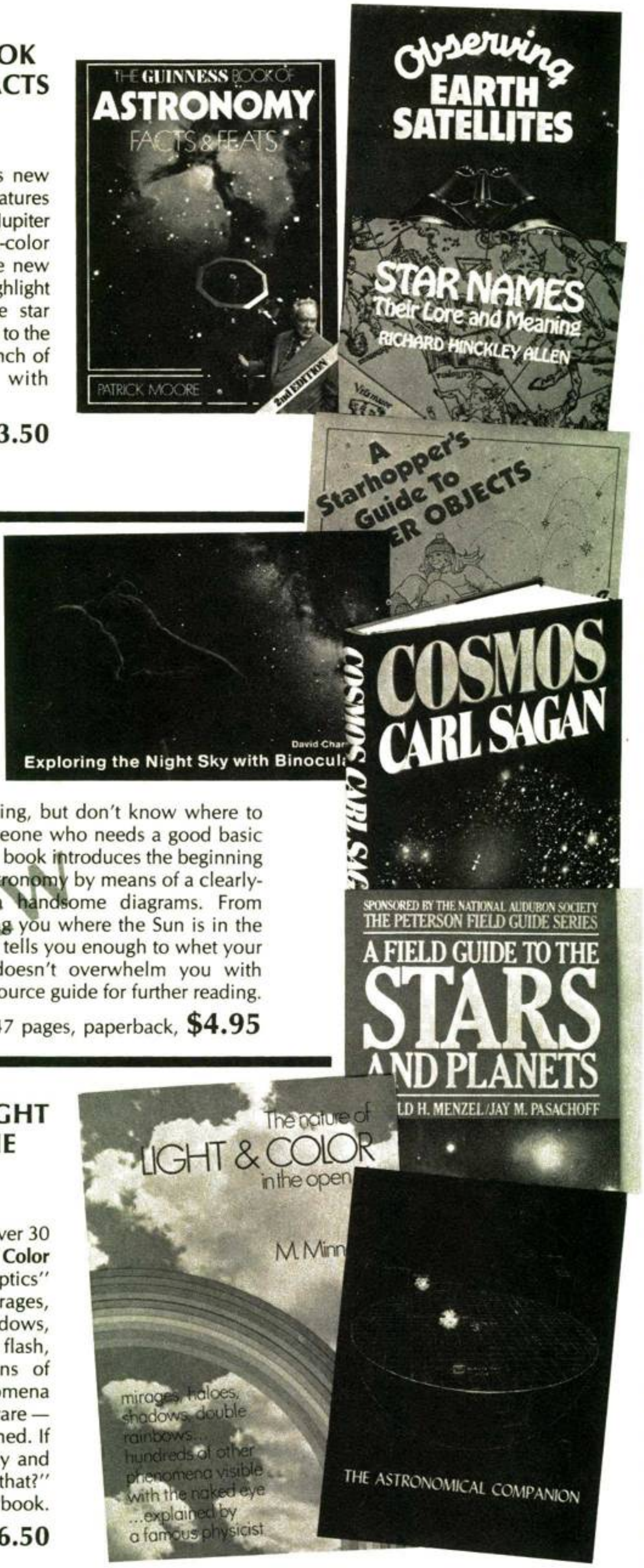
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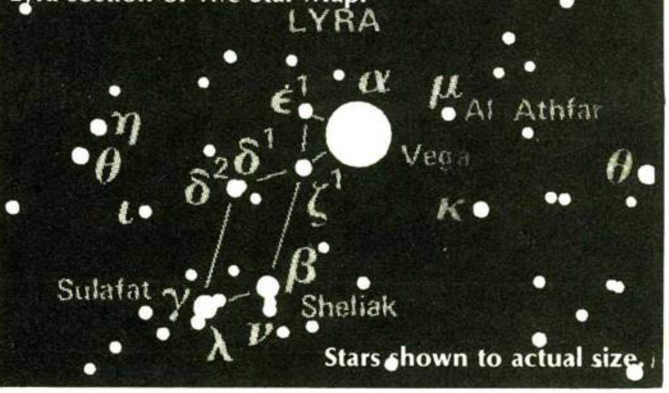

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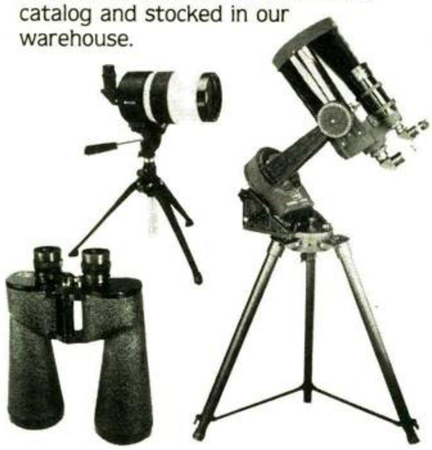

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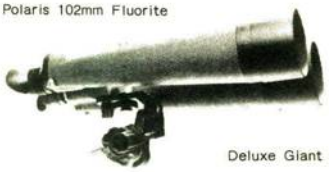

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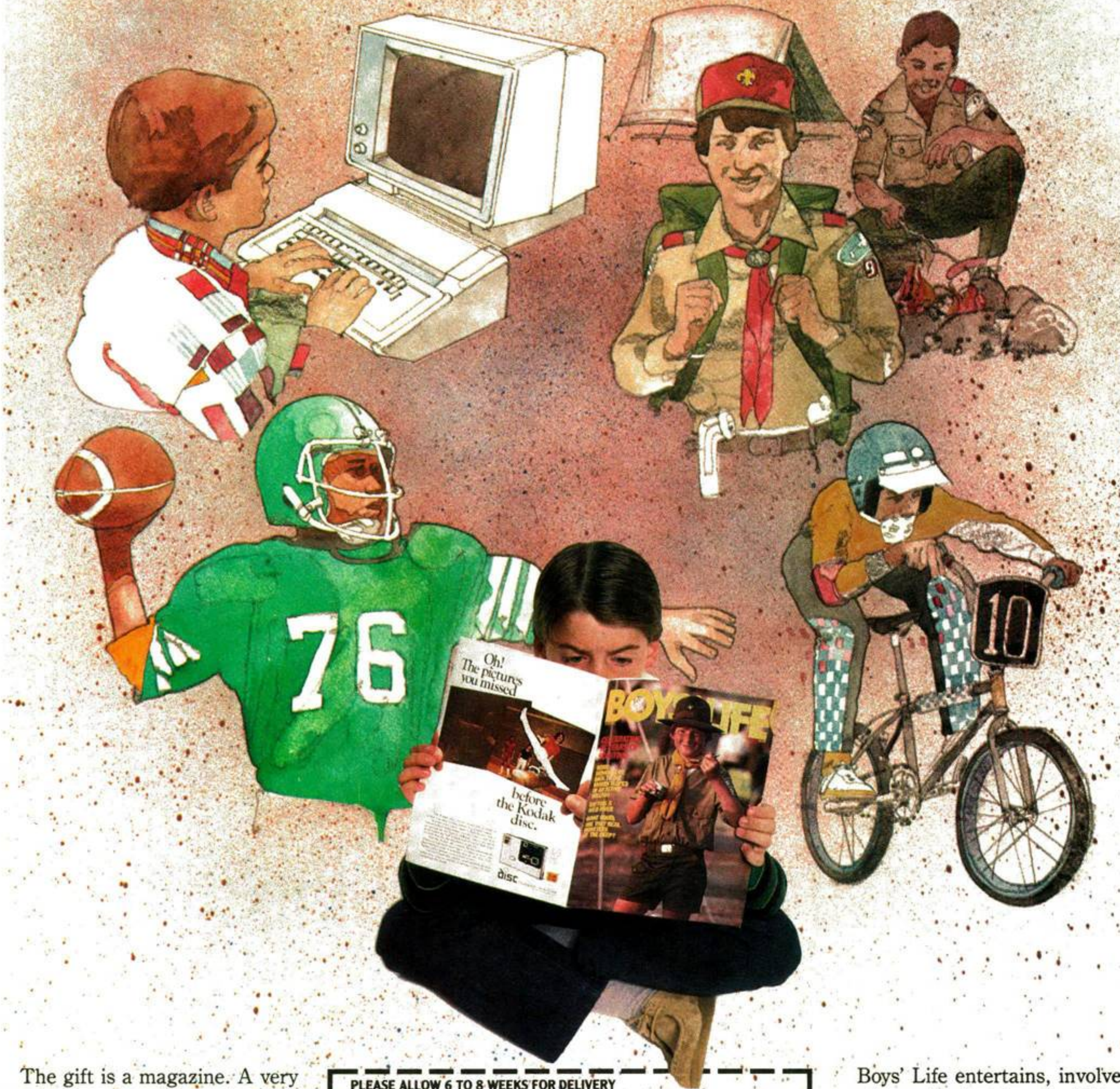

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# ASTRO NEWS

## Science and the Annular Eclipse

While May's spectacular annular eclipse offered many people the opportunity to witness an extraordinary event, a team of scientists at the Naval Research Laboratory used it to study the physics of the ionosphere. The eclipse took place around 12:20 p.m. Eastern Daylight Time, providing an ideal experimental situation for studying the ionosphere's response to a sudden change in conditions. This study has provided data that give a deep insight into the physics of the ionosphere and other important information that can be applied to such mundane uses as navigation and communications.

A solar eclipse differs from normal day-night radiation changes in that the duration of the change during an eclipse is short and affects an area over a limited zone about 2200 miles wide. Stephen Knowles, Francis Kelly, Mark Daehler, and William Waltman, who made up the NRL team, say that the eclipse gave them a chance to measure the propagation paths of very-low-frequency and high-frequency radio signals, to measure changes in the total electron content of the ionosphere, and to determine if any solar flares occurred.

To examine the ionosphere during the eclipse, the NRL science team used omega long-wavelength navigation signals reflected from the ionosphere to determine very-low-frequency propagation changes, and other radio signals for measurements of high-frequency propagation paths. They measured the changes in electron density of the ionosphere with NASA's Applications Test Satellite 6.

During the annular eclipse, NRL scientists found that there were no measurable changes in the effective height of the D-region (lower region) ionosphere because there was no measurable change in the received phase of the omega navigation transmissions from South Dakota or Argentina on 10.2 kHz and 11.3 kHz. The scientists did, however, find a noticeable depletion of the total electron content of the F-region (upper region) of the ionosphere as measured from the change in polarization of radio waves from the GOES-3 weather satellite on 136.38 MHz.

Any solar flare activity taking place during the eclipse would have been recorded by NRL's radio telescope at Maryland Point; the scientists noted no solar flares during the event.

## Mount Wilson in Jeopardy

Early in July the Carnegie Institution of Washington made an announcement to the astronomical community: funding for the Mount Wilson Observatory, which supports research mainly in solar and stellar astronomy, will be cut off effective July 1, 1985. This could leave the Observatory virtually shut down for good.

Over the last few decades, severe light pollution from Los Angeles has seriously compromised the effectiveness of the observatory. Carnegie's plan is to put more funding into their Las Campanas site in Chile, where the skies are dark and where a wider variety of research can be done. Two dozen telescopes of various apertures are now in operation there, and more may be built during the next few years.

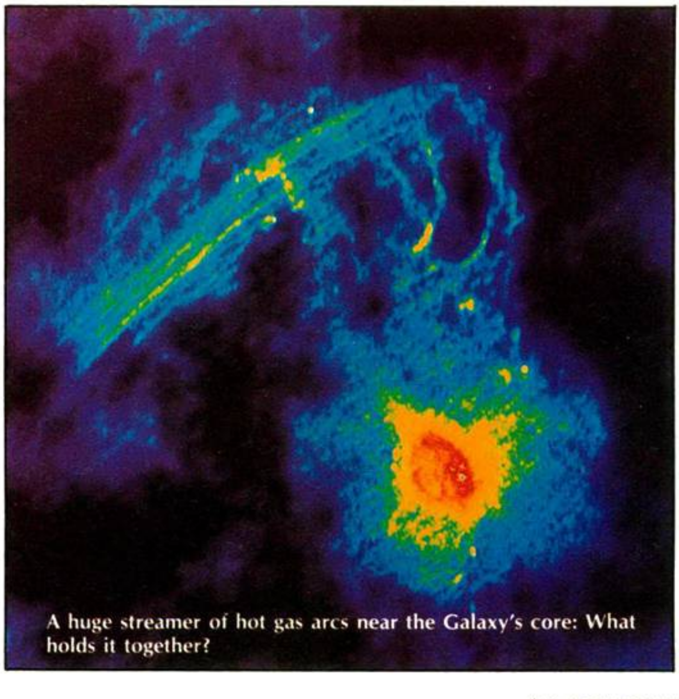
Meanwhile, Mount Wilson, whose 100-inch Hooker telescope (with which Edwin Hubble discovered the nature of galaxies in 1923), 60-inch reflector, and 150-foot and 60-foot solar towers have contributed much of our understanding of the universe, could be mothballed. Mount Wilson's director, George Preston, is optimistic that a new management system may be worked out, but there are major obstacles to overcome.

## Puzzling Structure Near Milky Way's Core

Astronomers have discovered a new structure near the center of our Milky Way Galaxy that is unlike anything previously seen — an enormous arc of hot gas more than 150 light-years long and composed of many narrow, filamentary features only a few light-years wide. The overall appearance of the newly found structure, which is about 30,000 light-years from Earth, resembles that of a solar prominence, a column of glowing gas that rises high above the Sun's surface. "Among the unique characteristics of this unparalleled structure is its coherent organization on such a large scale, suggesting that its presence is linked to the structure of our Galaxy," says Mark Morris, a member of the research team that made the find. Morris, an astronomer at the University of California at Los Angeles, headed the team with Farhad Yusef-Zadeh and Don Chance of Columbia University.

"The evidence now available, especially the detailed shape of the structure, implies that the arc of hot ionized gas is controlled by a magnetic field," remarks Morris. "While we've known for some time that our Galaxy contains a magnetic field, this is the first indication of the existence of a substantial poloidal magnetic field, akin to the dipole field of a simple bar magnet." Some planets of the solar system, including the Earth, have poloidal magnetic fields, as do the Sun and other stars. Such fields are theoretically understood in terms of a dynamo mechanism that generates them in a manner related to the way in which commercial electricity is generated by electric dynamos. Morris says that the new discovery may be revealing the existence of a galactic dynamo.

The presence of the structure could mean that stars are not being formed in the Galaxy's center at the high rate previously assumed on the basis of its intense radio emission. "The importance of understanding the activity in our galactic nucleus lies in what it may imply about the much more intense activity observed in the nuclei of radio galaxies, quasars, and other varieties of active galaxy," he adds. "We do not yet have a clear picture of why the tremendous quantities of energy released in such objects are manifested in their observed forms, but the presence of poloidal magnetic fields may provide an important clue."


NRAO

A huge streamer of hot gas arcs near the Galaxy's core: What holds it together?

## The Canterbury Swarm: A New Feature of the Solar System?

One of the tough things about astronomical detective work is trying to tie down a relationship between a few suggestive observations scattered throughout long periods of time. Consider these events:

- On June 25, 1178, a monk named Gervase of Canterbury reported that "the upper horn of the New Moon seemed to split in two and a flame shot from it." In the mid-1970s, scientists interpreted this description as an eye-witness account of the impact of an object with the Moon, even going so far as to suggest which crater it produced (Giordano Bruno). Laser ranging measurements of the Moon's rotation support this idea — the Moon still seems to be "ringing" from the impact.
- On June 30, 1908, a 12-megaton explosion occurred over the Tunguska region of Siberia. Based on its arrival time and direction of motion, one astronomer suggested

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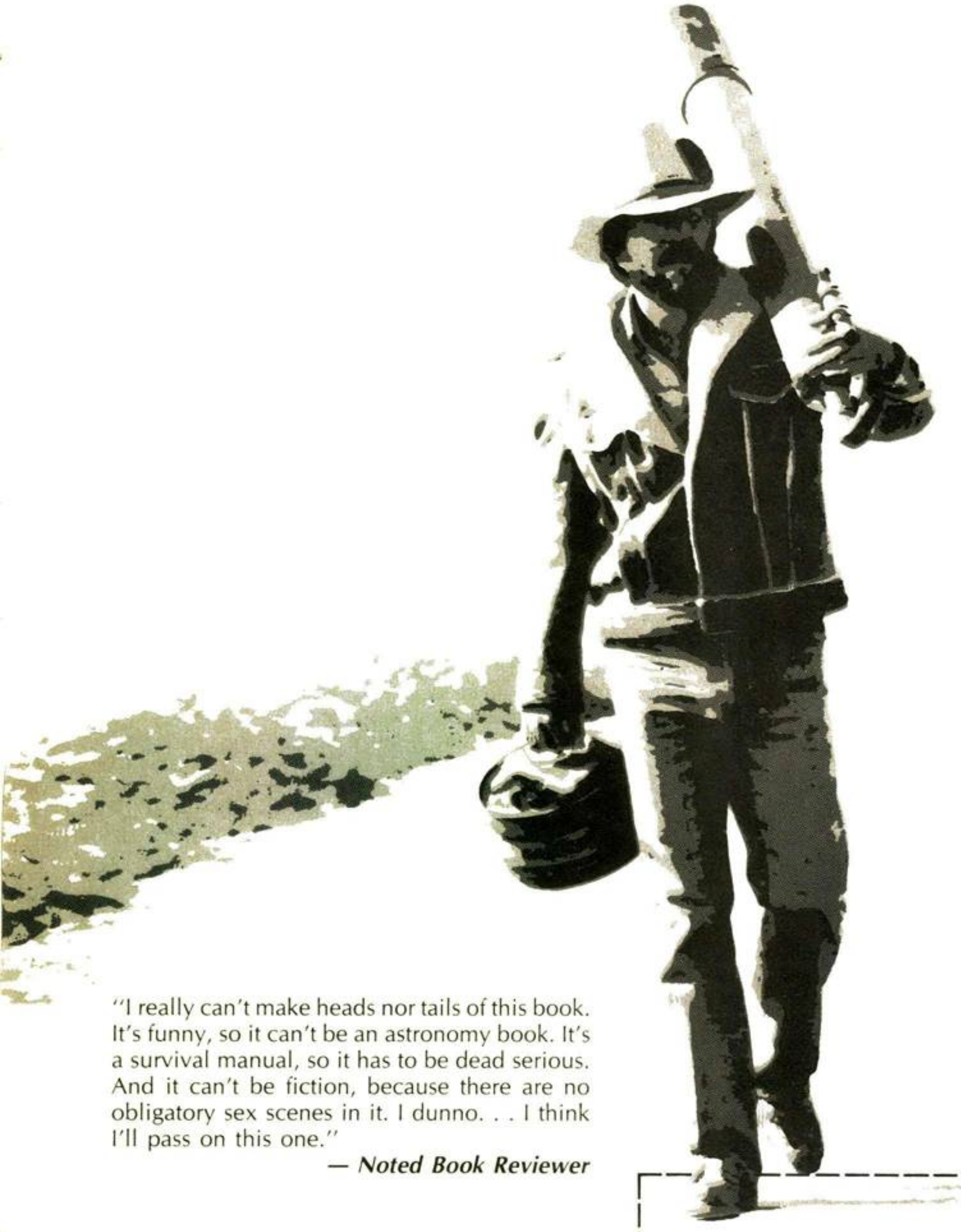

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— *Doris Fulton, wife of the author*

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in 1978 that the object was a fragment of Comet Encke. While this conflicts with more recent interpretations of the object's nature (see AstroNews, April 1984, p. 62), the question is far from closed.

- Between June 22 and June 26, 1975, the passive seismic network deployed on the Moon by Apollo astronauts detected impacts from a storm of meteoroids — the largest detected during the network's decade of operation.

"All of these events," claims Ken Brecher, an astronomer at Boston University and NASA's Goddard Space Flight Center, "are manifestations of a swarm of meteoritic or cometry material orbiting the Sun." The swarm arose from the break-up "either of Comet Encke or its progenitor some time prior to 1178," he argues. Brecher estimates that the swarm currently has a mass of about $10^{15}$ kg and consists of about 100 objects as large as one kilometer spread out over a volume of space nearly 15 million km across. Brecher calls the group the "Canterbury swarm," and believes it may be expanding at a rate of about one meter per second, orbiting the Sun in a path similar to that of Comet Encke with a period of 3.349 years. Encke's period of 3.30 years is the shortest of any known comet and is gradually decreasing due to the "rocket effect" of gaseous jets emanating from the comet's nucleus.

Brecher, who presented his findings at the June meeting of the American Astronomical Society, says that the swarm won't pass directly through the Earth-Moon system until June 2042. "But it should pass within 20 million miles of the Earth in June 1985," he notes. "We may be able to detect the swarm by infrared and optical observations."

## A New Look at Comet Encke

Comet Encke, now traveling between Earth and Venus, is losing water at a rate approximately three times higher than expected for its distance from the Sun. This surprising finding could be due to the particular arrangement of ice and dust that make up the comet, or to crumbling "mesas and hills" that may cover the surface of the comet's two kilometer (1.2 mile) diameter nucleus.

The Pioneer spacecraft in orbit around Venus made the finding. On April 13, mission controllers at NASA's Ames Research Center turned the long-lived Pioneer Venus orbiter away from the cloud-shrouded planet to look at the passing comet. The recent comet observation was only the second time that the orbiter has been used to observe an object other than Venus. The craft was launched in 1978 to make a detailed scientific study of Venus and continues to study the planet's atmospheric circulation.

Comet Encke is now closer to the Sun than the last time measurements were made (in 1980) so astronomers expected the rate of water evaporation to be higher — but only a third as high as the Pioneer observations indicate. Comets are thought to be made mostly of dust, rocky material, and water ice — dirty cosmic snowballs. But the distribution of cometary ingredients may vary, which could explain Encke's anomalous water evaporation rate.

Encke's ice and dust could be distributed unevenly, so that as the comet rotates (once every 6½ hours) it exposes different materials to the Sun. Particularly icy portions would vaporize faster. And since comets probably aren't smoothly spherical, surface irregularities like steep-sloped hills and mesas may also cause variations in the water evaporation rate.

To observe Comet Encke, NASA engineers tipped the Pioneer orbiter 37° to its orbital plane so that the craft's ultraviolet spectrometer could look at the comet. In addition to observing Comet Encke, researchers also rechecked the spectrometer's calibration by gathering data on the star Spica.

The UV spectrometer observed Comet Encke and Spica for about 1½ days, and the data were sent for analysis to scientists at the University of Colorado at Boulder. There, a team of researchers headed by Ian Stewart, the principal investigator for the UV spectrometer instrument on the Pioneer orbiter, calculated the comet's rate of water loss.

Because most atoms emit UV light when bathed in sunlight, measuring the wavelength and intensity of the emitted light can give scientists an idea of what elements are in a sample as well as how much of an element or compound is present. By measuring hydrogen emissions over a period of time, the Colorado researchers found that Comet Encke was losing water at a rate approximately three times higher than expected based on earlier measurements. Researchers analyzing data from the International Ultraviolet Explorer (IUE) satellite confirmed these results. The IUE, operated from NASA's Goddard Space Flight Center and in orbit around the Earth, observed Comet Encke from the end of April to mid-May.

## Giant Rings from Hercules A

Astronomers studying a distant galaxy have discovered a puzzling feature never seen before — a system of giant rings, each larger than our Milky Way, apparently being puffed out of one side of the galaxy. On the other side, the galaxy is emitting a twisting jet of hot matter. Such jets are not uncommon in radio galaxies, but this is the first time giant rings have been observed. The mysterious rings were discovered in the radio source Hercules A by John Dreher of the Massachusetts Institute of Technology and Eric Feigelson of Pennsylvania State University.

Using the world's most powerful radio telescope, the Very Large Array (VLA) near Socorro, New Mexico, the astronomers produced photographs using radio waves instead of visible light. "These rings are not smoke rings or bubbles being puffed out of one side of the radio galaxy, but they do present that appearance," says Dreher. "Their nature is currently a mystery."

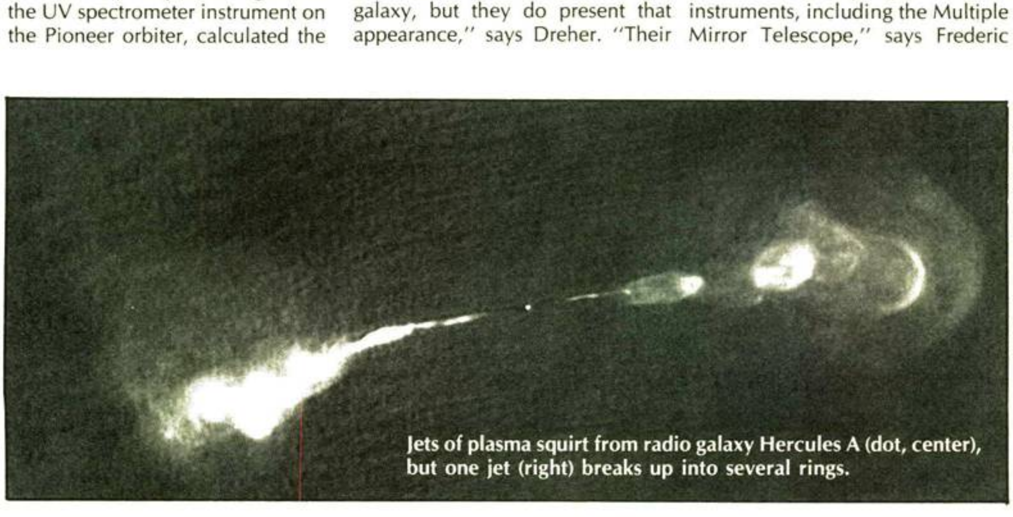
Hercules A, discovered in 1948, is one of the brightest radio sources in the sky and, like many radio galaxies, has an active "central engine" deep in its core. The galaxy is about two billion light-years from Earth and generates more than 100 billion times more energy in radio waves than the Sun does in visible light. The different appearance of the two jets — one a continuous stream and the other a series of distinct rings — might be due to differences in the environment into which they are ejected by the galaxy's central powerhouse. But the two astronomers think that variations in the central engine are also involved in producing the observed radio structures. Preliminary results of the findings have been published in the British journal *Nature*.

## Vista for Amateurs

The James Smithson Society of the Smithsonian Associates and the Fred Lawrence Whipple Observatory have established an "Amateur Astronomy Vista" in the foothills of the Santa Rita mountains on the road leading to the observatory's research facilities atop Mt. Hopkins.

The Astronomy Vista is designed for the use of all amateur astronomers throughout southern Arizona. The site, on the eastern slope of Montosa Canyon about nine miles from Interstate Highway 19, has concrete pads and benches for the placement of telescopes and other instruments and interpretative signs describing the flora, fauna, and geology of this rich nature area.

"We want amateurs to be able to share the same dark skies and clear viewing that have made the Santa Ritas the location for the Smithsonian's major ground-based instruments, including the Multiple Mirror Telescope," says Frederic



**Jets of plasma squirt from radio galaxy Hercules A (dot, center), but one jet (right) breaks up into several rings.**

NRAO photo courtesy John Dreher

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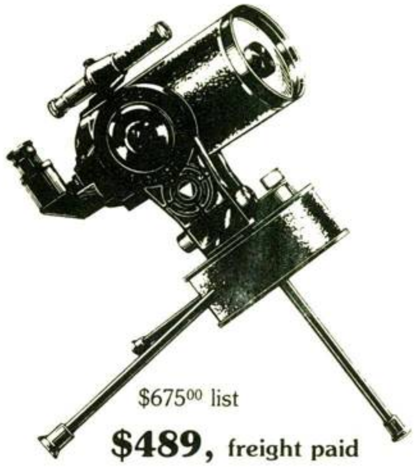

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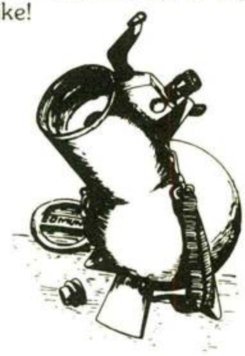

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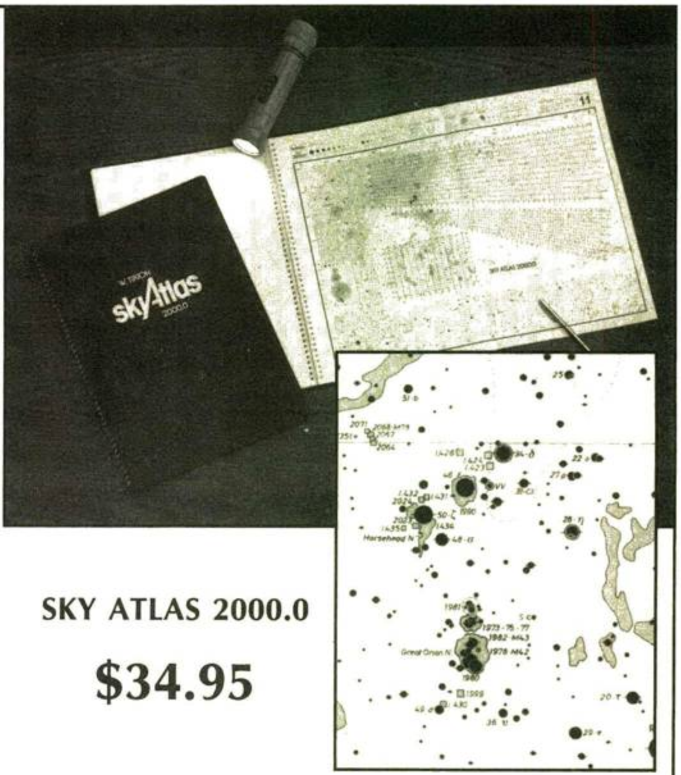

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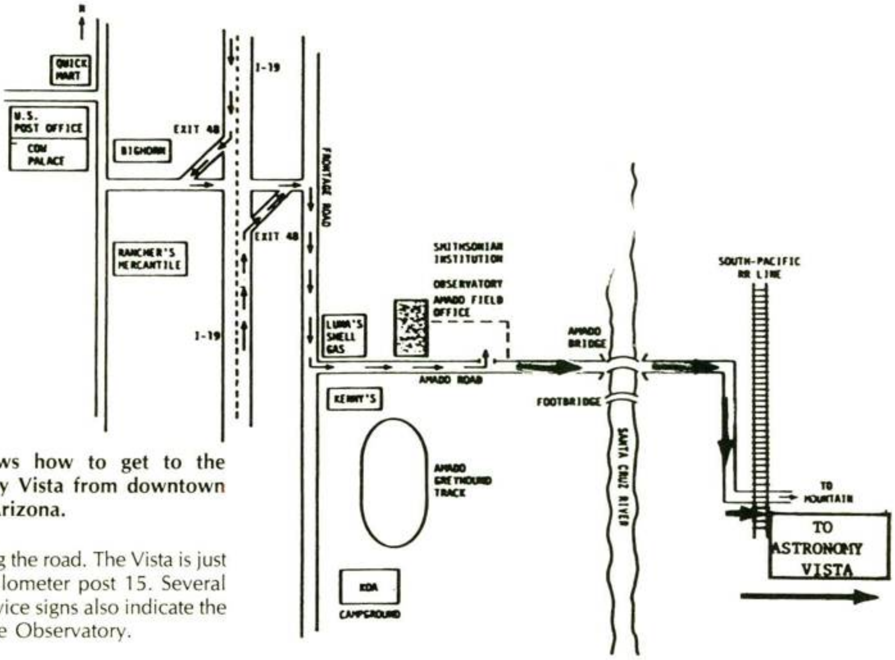
# ASTRO NEWS



**Map shows how to get to the Astronomy Vista from downtown Amado, Arizona.**

Chaffee, resident director of the Whipple Observatory.

The Astronomy Vista was officially dedicated on May 19. To get to the vista from Tucson (see map), take I-19 south to exit 48 at Amado. Exit the highway, turn left and proceed east under the freeway to the frontage road. Turn right and drive south about one mile. Turn left at Amado Road. After passing the Observatory field office you will come to the Santa Cruz River crossing. The bridge is washed out, so use the dirt-and-culvert causeway to cross. After crossing, turn right at the railroad tracks, following the road to the railroad crossing. After crossing the tracks, remain on this dirt road for the next seven miles to reach the Vista.

Several roads branch from the Observatory road, so make certain to remain on the one that looks best traveled. The Observatory has installed small redwood kilometer posts along the road. The Vista is just beyond kilometer post 15. Several Forest Service signs also indicate the way to the Observatory.

# ASTRO CALENDAR

**September 21-23**
**Astrofest.** Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477.

**September 22**
**Ohio Turnpike Astronomers Association Convention,** Akron, Ohio. Sponsored by the Astronomy Club of Akron. Contact: Philip Hegenderfer, 5070 Manchester Rd., Akron, OH 44319.

**October 6**
**Astro Assembly,** Seagrave Observatory, North Scituate, Rhode Island. Sponsored by Skyscrapers, Inc. Contact: Gerald Dyck, 418 High Hill, North Dartmouth, MA 02747.

**October 9-12**
**16th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society** (professional meeting), Kailua Kona, Hawaii. Contact: David Morrison, Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr., Honolulu, HI 96822.

**October 11-14**
**17th Annual Pacific Region Aerospace Education Conference,** Seattle, Washington. Contact: Jule Zumwalt, Director of Aerospace Education, Mather AFB, CA 95655. Phone (916) 364-4610.

**October 13**
**Telescope Users Clinic,** Whittier College, Whittier, California. Sponsored by Western Observatorium. Contact: Western Observatorium, 13215 E. Penn St., Suite 411, Whittier, CA 90602. Phone Bob Ferguson at (818) 795-4181.

**October 13-16**
**Conference on the Origin of the Moon** (professional meeting), Kona, Hawaii. Sponsored by the Lunar and Planetary Institute and the Division for Planetary Sciences of the American Astronomical Society. Contact: Pam Jones, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058. Phone (713) 486-2150.

**October 19-21**
**Sixth Annual Custer Astronomy Club Jamboree,** Southold, Long Island, New York. Contact: Warren E. Hamburger, President, 320 Asharoken Blvd., Bay Shore, NY 11706. Phone (516) 666-8654.

**October 19-21**
**13th Annual Meeting of the Great Plains Planetarium Association,** Waterloo, Iowa. Contact: Alinda Campbell, Grout Museum of History and Science, Waterloo, IA 50701.

**October 20**
**International Occultation Timing Association (IOTA) annual meeting.** Contact: Paul Maley, 15807 Brookvilla, Houston, TX 77059. Phone (713) 488-6871.

**October 24-27**
**Great Lakes Planetarium Association Conference,** Milwaukee, Wisconsin. Contact: Gary E. Sampson, Wauwatosa West High School Planetarium, 11400 West Center St., Milwaukee, WI 53222.

**October 26-27**
**AAVSO Fall Meeting,** Salem, Massachusetts. Contact: AAVSO, 187 Concord Ave., Cambridge, MA 02138. Phone (617) 354-0484.

**January 13-16, 1985**
**Meeting of the American Astronomical Society** (professional meeting), Tucson, Arizona. Contact: AAS, 1816 Jefferson Pl. N.W., Washington, DC 20036.

**February 15-17**
**First Annual Winter Star Party,** Everglades National Park, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Richard Fagin, P.O. Box 152, Miami, FL 33197. Phone (305) 233-5165.

**April 18-21**
**National Meeting of the National Science Teachers Association,** Cincinnati, Ohio. Contact: NSTA, 1742 Connecticut Ave. N.W., Washington DC 20009.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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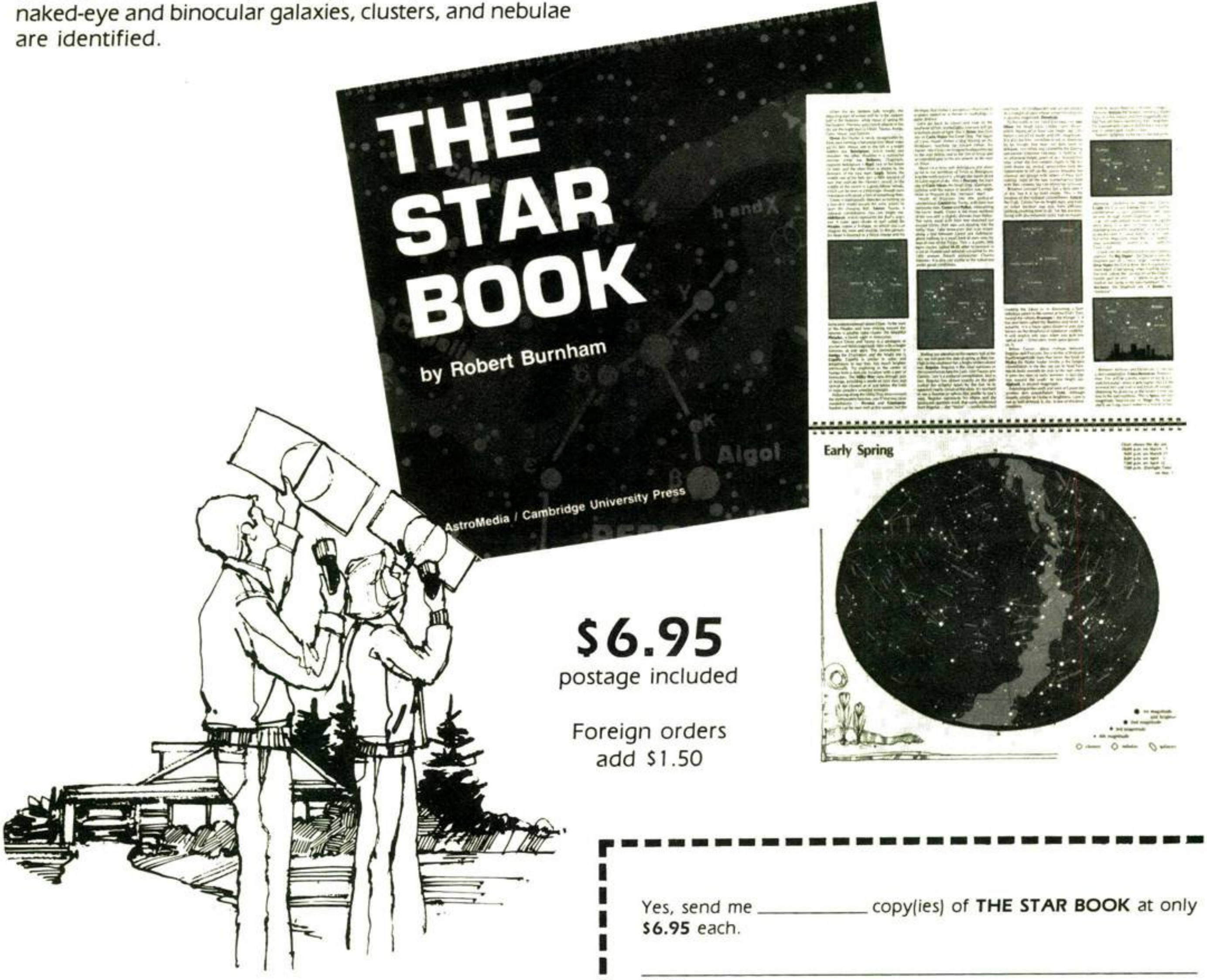

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# Are Quasars Far Away?

### by Jack W. Sulentic

The discovery of quasars in the early 1960s was one of the major advances in astronomy this century. By 1964, it appeared that astronomers had discovered a new constituent of the universe. Quasars appeared to lie at great distances, suggesting that they represented an earlier chapter in the history of the universe — a look backward in time.

What are quasars? Observationally, they are star-like objects which radiate large amounts of energy in the blue and ultraviolet regions of the spectrum. In addition, some quasars emit stupendous amounts of radio energy, though the majority are not radio sources at all. But the two strangest properties of quasars are the large redshifts of their spectra and their frequent and rapid changes in brightness. If we interpret their redshifts as conforming to the Hubble distance relation — which states that the amount a galaxy's spectrum is shifted toward the red is directly proportional to the galaxy's distance — then quasars lie at extremely large distances.

Quasars are not merely at large distances, but are bright enough for us to see at large distances: they are therefore the most luminous objects in the universe. At the same time, the short timescale of their changes in brightness — weeks to months — implies that the quasars are only several light-weeks to light-months across, assuming that they radiate energy the way "normal," understandable objects do. How an object less than a light-year across can give off more energy than a galaxy with 200 billion suns is an exceedingly perplexing problem.

All of this depends on the Hubble relationship. For normal galaxies, this is fairly well established. But do quasars obey the same law? This is an uncomfortable question, because we really don't know what quasars *are*. We suspect strongly that they are intimately related to galaxies, perhaps an early stage all galaxies pass through. But if you could argue that some or all quasars had non-distance-related redshifts, then the entire Hubble relation is placed in jeopardy. Indeed, we would need a new physical theory to explain the "non-Doppler" component of the redshift. Astronomers generally agree that most galaxies show redshifts proportional to their distances; the frightening prospect is suspecting that some objects might not have "normal" redshifts.

Many astronomers reason that since physics has not failed in the past, we should keep the faith that a theory will emerge to explain the quasar business. Black holes as giant central "engines" are one possibility often suggested, allowing quasars to tap the plentiful gravitational energy in the universe. Other astronomers argue that Hubble redshift distances to quasars must be wrong — that quasars must really be much closer than their redshifts indicate. Decreasing the distances to quasars explains away the energy problem, since nearby quasars need no longer be exceptionally bright.

During the 1960s and early 1970s, astronomer Halton C. Arp of Mt. Wilson Observatory found a number of quasars located at small angular distances from low-redshift galaxies. One of the best examples are the quasars near NGC-1073, a 12th magnitude barred spiral in Cetus. The galaxy's redshift implies that it is about 16 megaparsecs distant (1 Mpc equals 3,260,000 light-years), but the quasar's redshift indicates a distance of over 1,000 Mpc! This might be understandable as the chance positioning of a quasar near NGC-1073, were it not for two more quasars — whose redshifts also indicate distances greater than 1,000 Mpc — seen near the galaxy's arms. Could three quasars *happen* to lie in line with this galaxy? Most astronomers would answer yes. But a vocal minority argues that too many galaxy/quasar "pairs" have been found for it to be coincidental. In one survey, 15 quasar/galaxy pairs were discovered where astronomers expected to observe only two. In another, which looked at fields surrounding nearby spiral galaxies, astronomers identified 26 quasars where they expected only 15.

Another controversial discovery, made about 10 years ago, was finding several close pairs and groupings of quasars with different redshifts. The close pair of quasars, called 1548 + 114

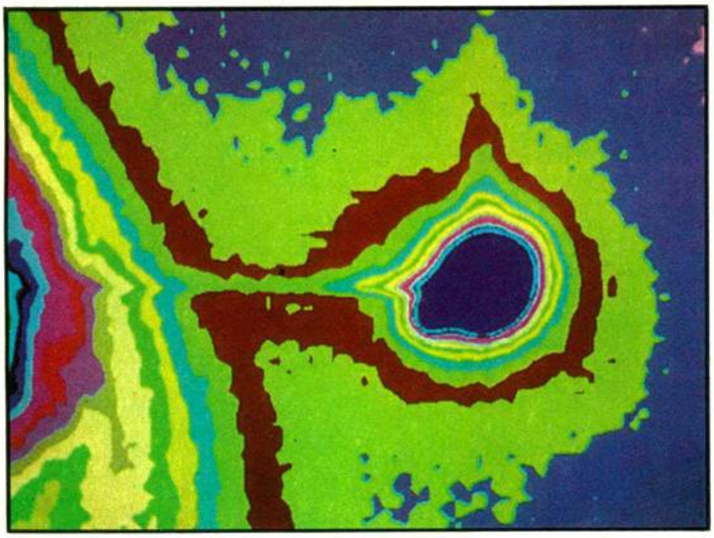
## The Discovery of the Quasars

In the early sixties, astronomers were just beginning to determine the positions of radio sources on the sky. Most of the radio emission from outside the Milky Way appeared to be coming from distant galaxies. A surprise came, however, in 1963 — astronomers found that a few radio sources coincided with *stellar* objects. But stars, other than the Sun, are too far away for us to detect their relatively weak radio emission — something very strange was going on.

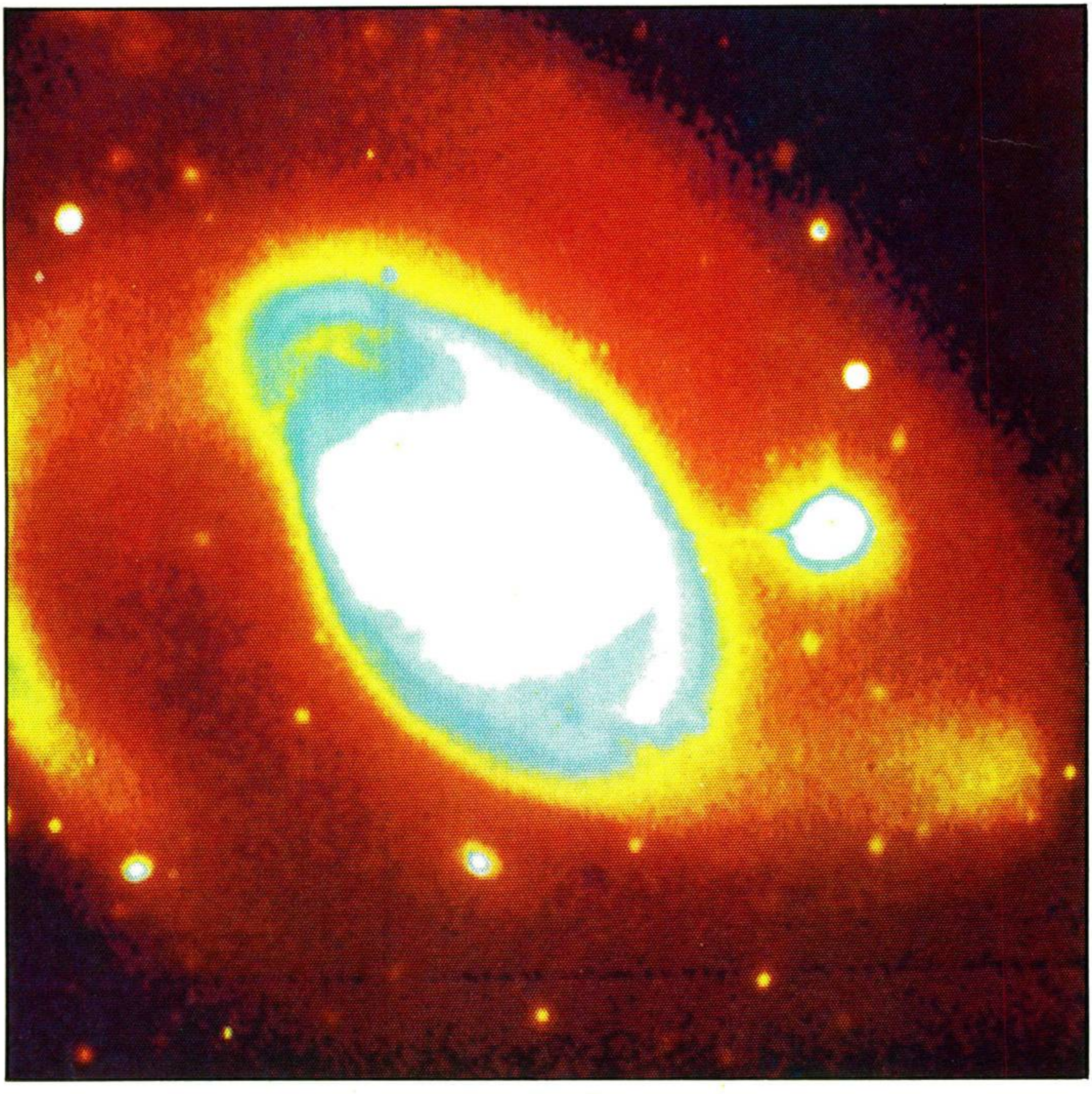
The positions of these "radio stars" were given to astronomers at Palomar Mountain Observatory. Spectra taken with the 200-inch Hale reflector revealed that these objects did not show the absorption line spectra of stars. Instead, their spectra contained bright emission lines, indicating regions of excited gas. The exact nature of the lines and their spectral shift was, for a time, unknown.

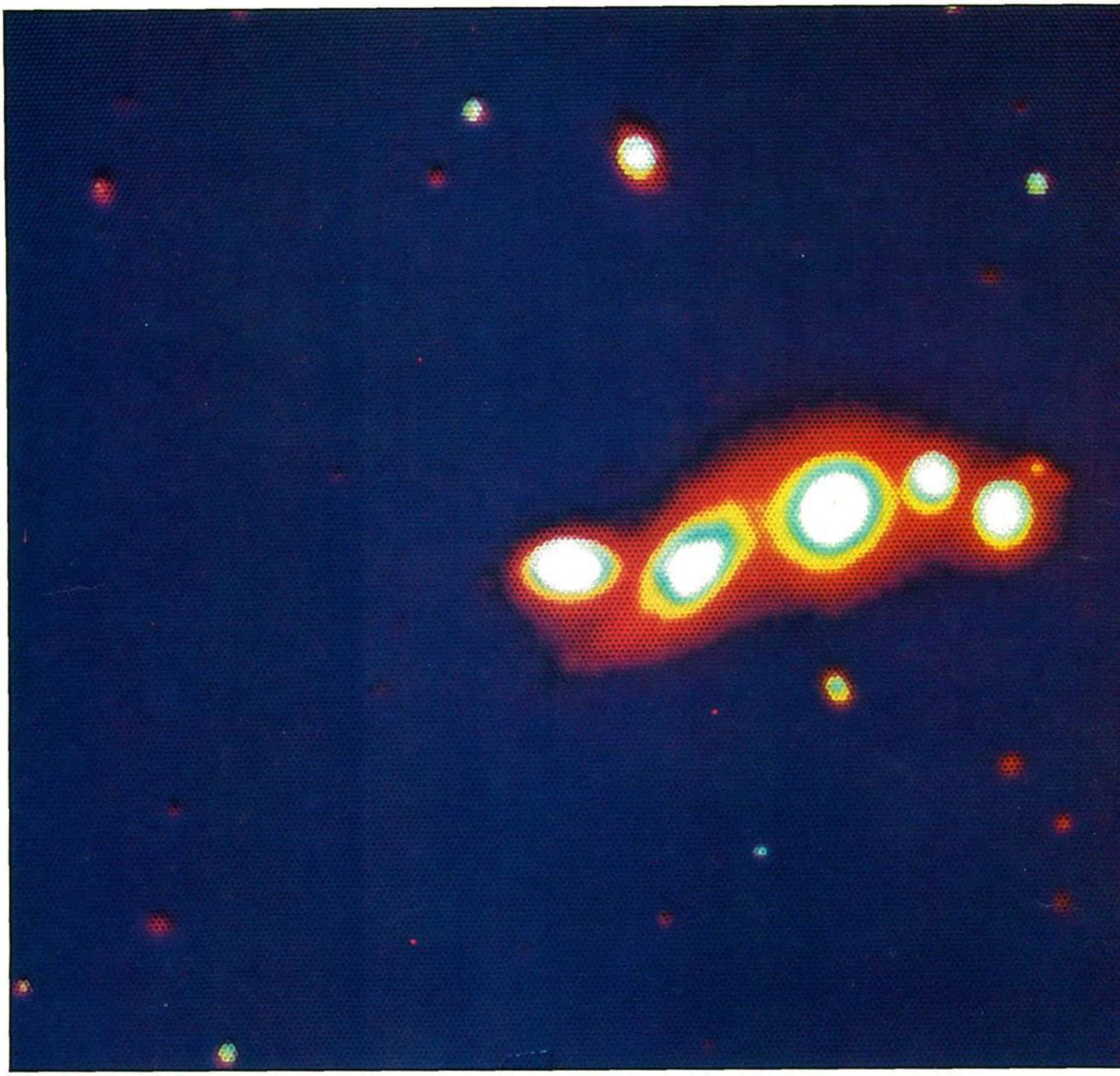
Then, Maarten Schmidt of Caltech obtained a spectrum of the object 3C-273 in Virgo. He soon realized that the principal lines in its spectrum were due to ordinary excited hydrogen gas. But the lines were redshifted so much that they indicated a recession velocity for the object of 16% of the speed of light — which placed 3C-273, according to the Hubble law, far beyond the nearby galaxies. Redshifts in other quasi-stellar radio sources, as they were called, indicated that they were even more distant.

Not long after this discovery, Allan Sandage of Mt. Wilson Observatory found a few "stars" with high-redshift optical emission lines but no radio emission. Today we refer to these objects as radio-quiet quasars. In the 20 years since their discovery, the list of all known quasars has grown to 2250.



**Below: After special processing, this 5-meter Hale telescope photo shows a luminous connection between the spiral galaxy NGC-4319 and the quasar Markarian 205 (just to the right of the galaxy's nucleus). According to its redshift, the quasar should be 280 megaparsecs away — 116 percent farther than the galaxy. Yet the galaxy and quasar appear to be physically associated. The thin line running left to right is a CCD transfer flaw — the bridge is wider and appears light green. Far left: The original exposure, digitized and printed in black and white. Left: A computer-enhanced closeup of the bridge, which appears reddish-brown: Does this object cast the Hubble distance relation into doubt? All photos in this article are by Jack W. Sulentic.**





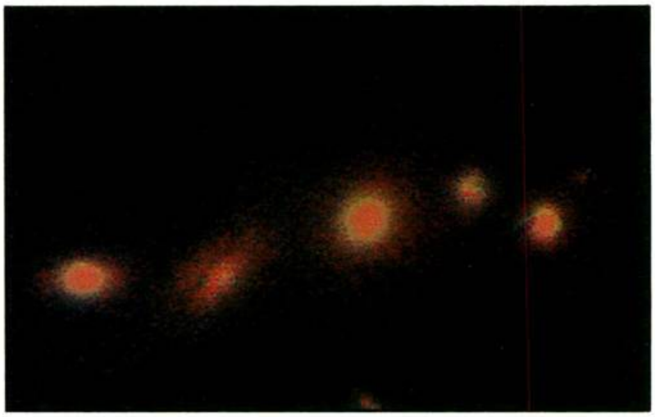
(for its approximate coordinates), were separated on the sky by only five arc-seconds. Taking their redshifts as distance indicators, they lie at enormously different distances in space. In a review of quasar research a few years ago, astronomer Fred Hoyle remarked that the redshift controversy might not have happened had this pair been found in 1965 instead of 1972. The unlikelihood of a pair of unrelated quasars lying on the same line of sight might, he suggested, have led astronomers to reject redshifts as distance indicators altogether!

At about the same time astronomers found quasar pairs, redshift inconsistencies between galaxies arose. Stephan's Quintet is a group of five 13th magnitude galaxies in Pegasus, all of which show streamers of material overlapping each other. This is fine and good, since we know about many interacting pairs of galaxies. But in this case the redshift of NGC-7320, the brightest of the five, is one-eighth that of three of the other four. Yet it appears connected to the other galaxies by a bridge of matter. We are forced to choose between the apparent connection on the one hand, and the validity of the distance derived from one galaxy's redshift on the other. Which is right?

Two more galaxy groups containing members with discordant redshifts are known: VV172 (from the catalog of galaxies by Russian astronomer Boris Vorontsov-Velyaminov) and the NGC-6027 group in Serpens (also known as Seyfert's Sextet, after the American astronomer Carl Seyfert). In each of these cases, one of the galaxies possesses a much higher redshift than the others. Of course, it can be argued that the galaxies with similar redshifts are interacting while the discordant member coincidentally happens to fall in line with the others, and really lies behind them. Statistically, however, this is unlikely. A study of the rare, strongly interacting galaxy groups has recently led me to calculate that no more than a single discordant redshift system should exist merely by chance. Five are known, however, and redshifts do not yet exist for other possibly interacting groups.

Then there is the strange case of NGC-7603 and its companion. NGC-7603 is an 11th magnitude galaxy in Pisces, which harbors a smaller, fainter galaxy at the end of one of its arms. There is less doubt about the interaction in this case than in other cases — a single arm of the bright galaxy appears to "reach out" directly toward the smaller galaxy. Yet the small

Galaxy/quasar pairs aren't the only phenomenon forcing a careful look at the Hubble relation. Left: This computer-enhanced view of the chain of five galaxies known as VV172 was made with the 4-meter Mayall reflector on Kitt Peak; it shows the discordant redshift galaxy (second from right), which appears to be embedded in a halo surrounding the entire group. Below: A false-color view made with the 5-meter telescope shows the same galaxy as slightly more blue than the rest.



galaxy has a much higher redshift than NGC-7603.

In the past 15 years, astronomers have weighed two types of evidence that support the concept of non-Doppler redshifts. *Statistical* evidence involves determining the probability of finding as many quasars as we have found near galaxies, or the probability of finding discordant redshifts among galaxies in groups by chance.

One problem with statistical arguments is that actual numbers of quasars and galaxy groups are poorly known; consequently, it is difficult to predict how many accidental associations should occur by chance. In the 1970s, though, some studies purported to show that the observed number of discordant redshift associations was in fact equal to the number expected to occur coincidentally.

*Direct* evidence involves finding connections or interactions between objects showing different redshifts. This is extremely controversial, as most astronomers simply deny any relationship between such objects, arguing they must be accidental. Moreover, new evidence is emerging which may support the standard belief that quasars really are far away. Diffuse halos

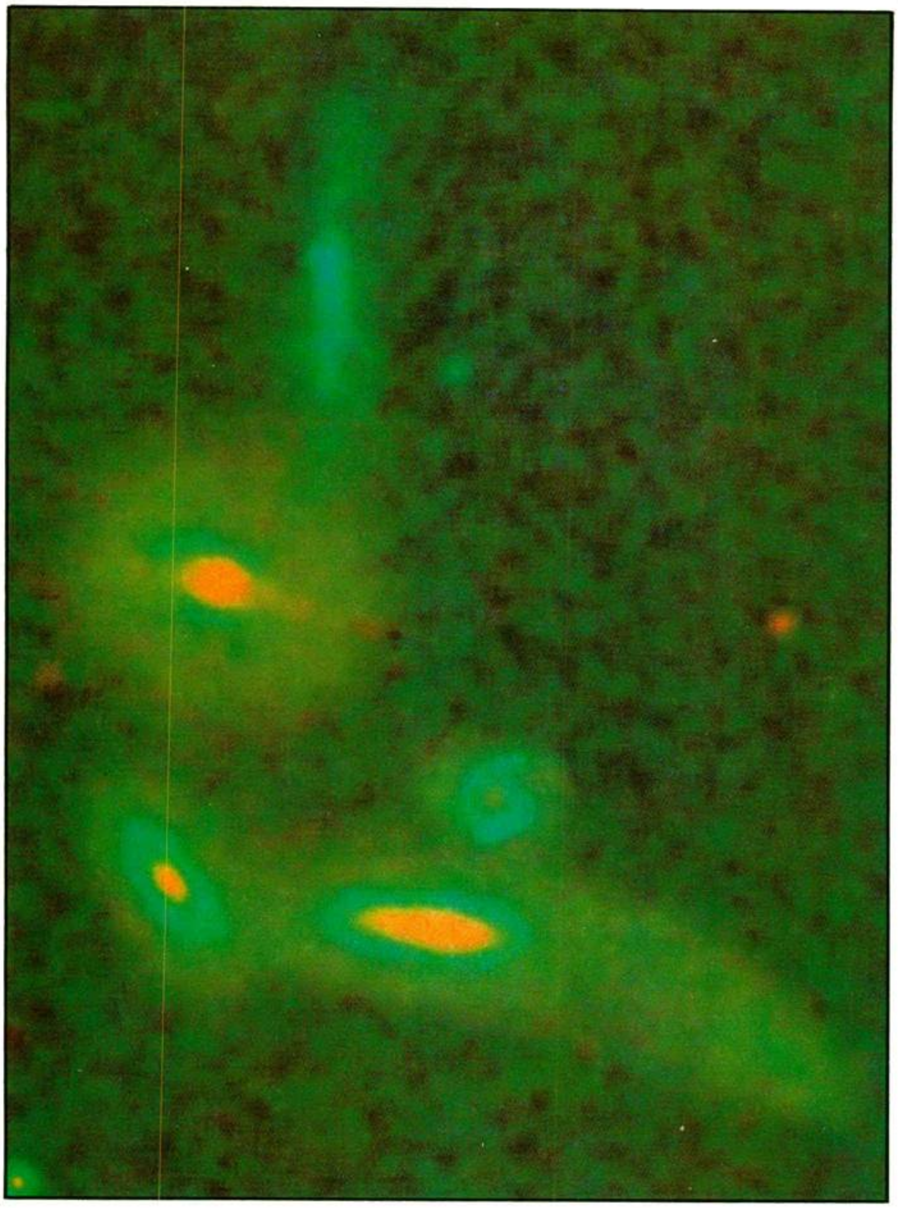
## Halos Around Quasars — Proof of Large Distance?

The discovery of luminous "fuzz" around the edges of quasars may be an important development. The idea that quasars have halos goes all the way back to their discovery, but since data collected 20 years ago were relatively poor — and skepticism high — these structures could not be identified with certainty. Strong evidence for luminous halos surrounding quasars has come with the development of more sensitive light detectors for telescopes and the advent of digital computer processing techniques for the data.

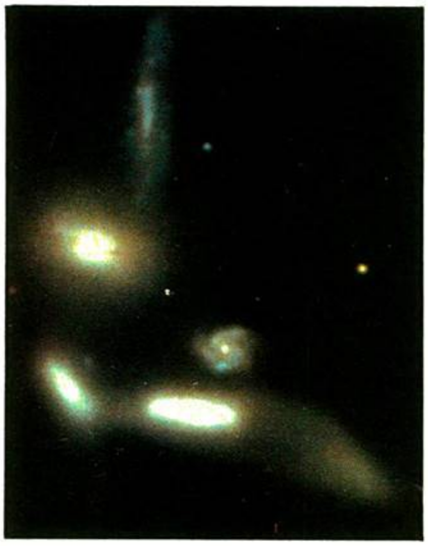
Many astronomers regard the luminous halos as proof of the quasars' true redshift distances because the fuzz is visible around most of the low-redshift quasars, but not around those of high-redshift. If redshifts are indeed distance indicators, the low-redshift quasars are closest to us and therefore are the ones in which we would expect to see the fuzz. The halos tend to be redder in color than their accompanying quasars — again suggesting that we may be seeing the underlying galaxy which contains a quasar in its center.

Therefore, you might conclude, quasars reside in galaxies — we see the galaxy around the nearby quasars, but high-redshift quasars lie too far away to reveal their home galaxy. Presumably, since galaxies obey the "Hubble law," the quasars inside them must, too.

A handful of astronomers disagree with this because some galaxies in groups show discordant redshifts (and maybe quasars do, too), and spectra do not yet exist to show that the "fuzz" represents a galaxy. Finally, the halos are so big that they imply huge galaxies — perhaps four or five times the size of the Milky Way.



**NGC-6027, the group of interacting galaxies called Seyfert's Sextet, also suggests an intimate association between members. Left: In this false-color photo the galaxy with the discrepant redshift appears as a circular blue smudge directly above the flattened disk galaxy. Below: A normal photo shows that the little galaxy is a face-on barred spiral.**



have been discovered around a number of the relatively low-redshift quasars. The color and brightness of these halos are what astronomers would expect if this "fuzz" were the light of a galaxy surrounding the quasar. Many astronomers feel that this new evidence links quasars and galaxies so strongly that it invalidates all evidence in support of non-Doppler redshifts.

Yet the controversy continues. Halton Arp, one of the first astronomers to hold the non-Doppler viewpoint, is still finding more hard-to-explain-away examples. As his working hypothesis, Arp believes that large, normal galaxies are the sites of violent ejection activity. Quasars might be shot from galactic nuclei at high speed (high redshifts) and later might become normal galaxies with normal Doppler redshifts.

Curiously enough, the redshift controversy almost came to an end in 1971, when Arp published a photograph of the galaxy NGC-4319. It shows the spiral galaxy NGC-4319, with the quasar Markarian 205 below its nucleus and within its arms. The redshift of the quasar indicates that it is over 10 times more distant than the galaxy — 280 Mpc as opposed to 24 Mpc. But a luminous connection exists between the two objects. Confirming this link would prove the existence of a non-Doppler redshift. During the 10 years following Arp's publication of the original photograph, a flood of analyses were published that reached one or more of three conclusions: (1) the connection does not exist, (2) the connection exists but is a photographic artifact, not a real object, or (3) the connection is artifically created by small faint stars or background galaxies falling between the two objects. Astronomers simply didn't believe Arp's evidence.

The case seemed lost until I made a detailed digital image analysis in 1982, using the image processing facilities at Caltech's Jet Propulsion Laboratory. The analysis shows a narrow connection, not a photographic artifact, which can be traced into the nucleus of NGC-4319. It is now difficult to deny that a narrow linear feature actually lies between the galactic nucleus and the quasar. Is this feature an "ejection path," or is it the result of a highly improbable accident?

The controversy will probably not rage on much longer; it seems likely that the debate will be resolved in the next 10 years. By that time, better samples of quasars will become available to address the statistical side of the question, and new ground-based techniques, along with the orbiting Space Telescope, will permit detailed studies of high-redshift "oddballs" in galaxy groups. There will be no losers in the end: the controversy will have forced us to scrutinize our ideas about extragalactic astronomy — and to take a more careful look than we might otherwise have taken.

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*Jack W. Sulentic is Associate Professor of Astronomy at the University of Alabama and a former staff member of the Hale Observatories. His primary research involves radio and optical observations of galaxies and quasars. He is co-author of the* Revised New General Catalogue.

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ANNOUNCEMENT — The Southern Cross Astronomical Society invites all to attend our first informal winter star party, February 15-17, 1985. Everglades National Park, southwest of Miami, Florida. For an information packet, contact Richard Fagin, P.O. Box 152, Miami, FL 33197. Phone (305) 233-5165.

ANNOUNCEMENT — The Wilderness Center Astronomy Club, located southwest of Canton, Ohio, invites all amateur astronomers in the Canton, Wooster, and New Philadelphia areas to attend meetings on the last Friday of each month at 7:30 p.m. Call Dave Gill at (216) 833-9399 for information.

ANNOUNCEMENT — The Webb Society, an international deep-sky observers organization, is open for membership. A quarterly journal is published. Interested observers should contact Ronald J. Morales, 1440 S. Marmora, Tucson, AZ 85713.

ANNOUNCEMENT — The third annual Astrofest, sponsored by the Santa Barbara Museum of Natural History and Santa Barbara City College, will be held on October 13 and 14. Contact Astrofest, Museum of Natural History, 2559 Puesta del Sol Rd., Santa Barbara, CA 93105.

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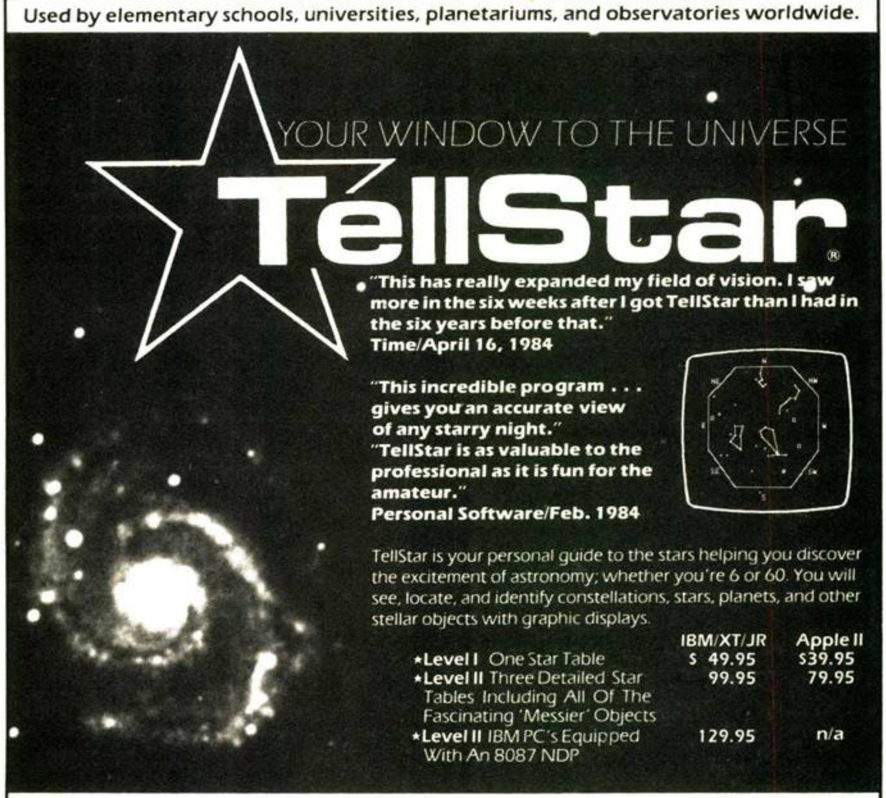

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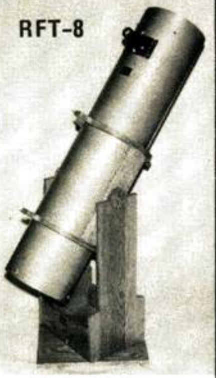

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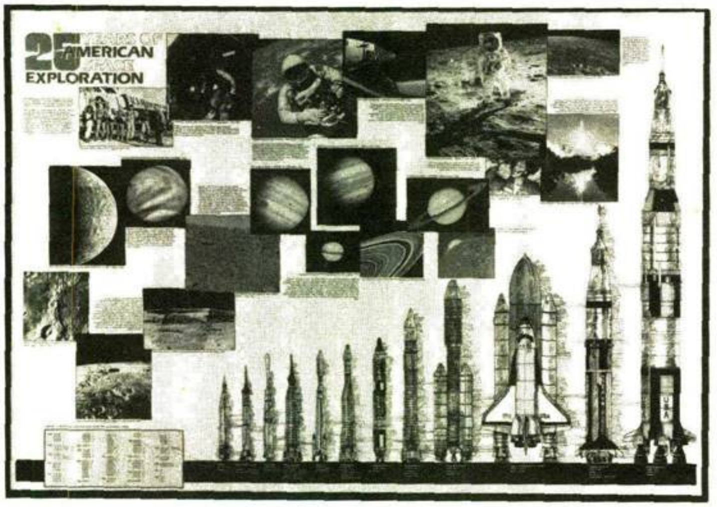

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# How to Choose a Deep-Sky Telescope

Equipment Atlas

Let's say that you're interested in buying a telescope and that you want to use it, at least some of the time, for observing deep-sky objects. This is entirely reasonable, considering that *everything* in the sky, except for solar system stuff, is a deep-sky object. What kind of telescope should you get? As with any type of specialized observing, no single telescope does everything equally well. You must first decide what type of deep-sky observing you wish to concentrate on, and then you can narrow the possibilities and get a telescope that will meet your specific needs. But remember not to go overboard: a telescope is something heavy you will have to lug around. A smaller, shorter focal length model will get used more often because it is relatively easy to carry.

Basically, deep-sky objects can be lumped together into four broad categories that describe their appearance. The Big, Faint Fuzzies group includes everything larger than ⅓ degree and particularly those with a low surface brightness. Variable stars are those which, for a variety of reasons, change their light output. High-resolution objects include double stars, small galaxies, planetary nebulae, and globular clusters. And run-of-the-mill galaxies are average unspectacular objects.

### Big, Faint Fuzzies

The "Big, Faint Fuzzies" category contains objects whose diameter exceeds 20 arcminutes, or ⅓ degree. This group includes big galaxies, low-surface-brightness emission and reflection nebulae, scattered open clusters, and dark nebulae. To view these objects successfully, you'll need a telescope that meets a couple of specific demands. It should provide a wide field of view when used with a long focal length eyepiece — preferably showing between one and two degrees of sky. Having this much sky around your target makes it easier to find and gives you a comfortable view. Your scope should, of course, have excellent optics. It should also have lots of light-gathering power and the capability of providing low magnification so that its images are bright.

The best telescopes for large, faint objects are Newtonian reflectors, mounted equatorially or Dobsonian-style. Newtonians use two mirrors — a parabolic primary and a flat secondary — and typically come in focal ratios from f/4 to f/10, with tube lengths ranging from 3 to 6 feet long. You'll probably want to get an f/5 or f/6 instrument, as it will offer better portability for the same aperture. The cost of a 6-inch Newtonian, which will show you all of the Messier objects and hundreds of NGC and IC objects, ranges from $300 to $600, but costs less if you assemble it yourself from components.

Of course, larger apertures will show you fainter deep-sky objects and will reveal more and more detail in the brighter galaxies and nebulae. A 10-inch easily reveals the dark lanes in the Trifid Nebula, the central stars of many planetary nebulae, and the faint outer arms of the brightest spiral galaxies. For a telescope mounted equatorially, the price rises to $1200 to $1500, rather than $600 for our 6-inch model. But if you want a telescope for visual observing, you can buy a Dobsonian — a Newtonian reflector simply supported like a mortar, with up/down, left/right axes of movement. This cuts the cost dramatically. A Dobsonian is simple to use after you learn how to bump the object back into the scope's field of view every once in a while. A 10-inch Dobsonian costs no

Large, faint objects like nearby galaxies and low surface brightness nebulae are some of the sky's most elusive telescopic showpieces. Photo of M-16 by John Gleason.

You can follow the fluctuating brightnesses of variable stars using almost any telescope. Photo by Brian Skiff.

Globular clusters, small galaxies, double stars, and planetary nebulae require much higher resolution and magnification than big galaxies and nebulae. Photo of M-71 by Bill Iburg.

more than a 6-inch reflector mounted equatorially.

If you're interested in seeing absolutely everything, and can accommodate a large instrument weighing 300 to 400 pounds, large Dobsonians are perfect. Both 16-inch and 17.5-inch models are currently available for $1000 to $1800 — the same price range as an equatorially mounted 10-inch. These large-aperture "light-buckets" must be used under dark skies, which means you must either own a site where the telescope can stay, or cart it out when you want to observe. That can be a problem, but if you're a deep-sky fanatic, the views will more than make up for the effort. Telescopes in the 16-inch-and-up range can literally show you every object in the *Revised New General Catalogue*, and astonishing detail in the brighter objects.

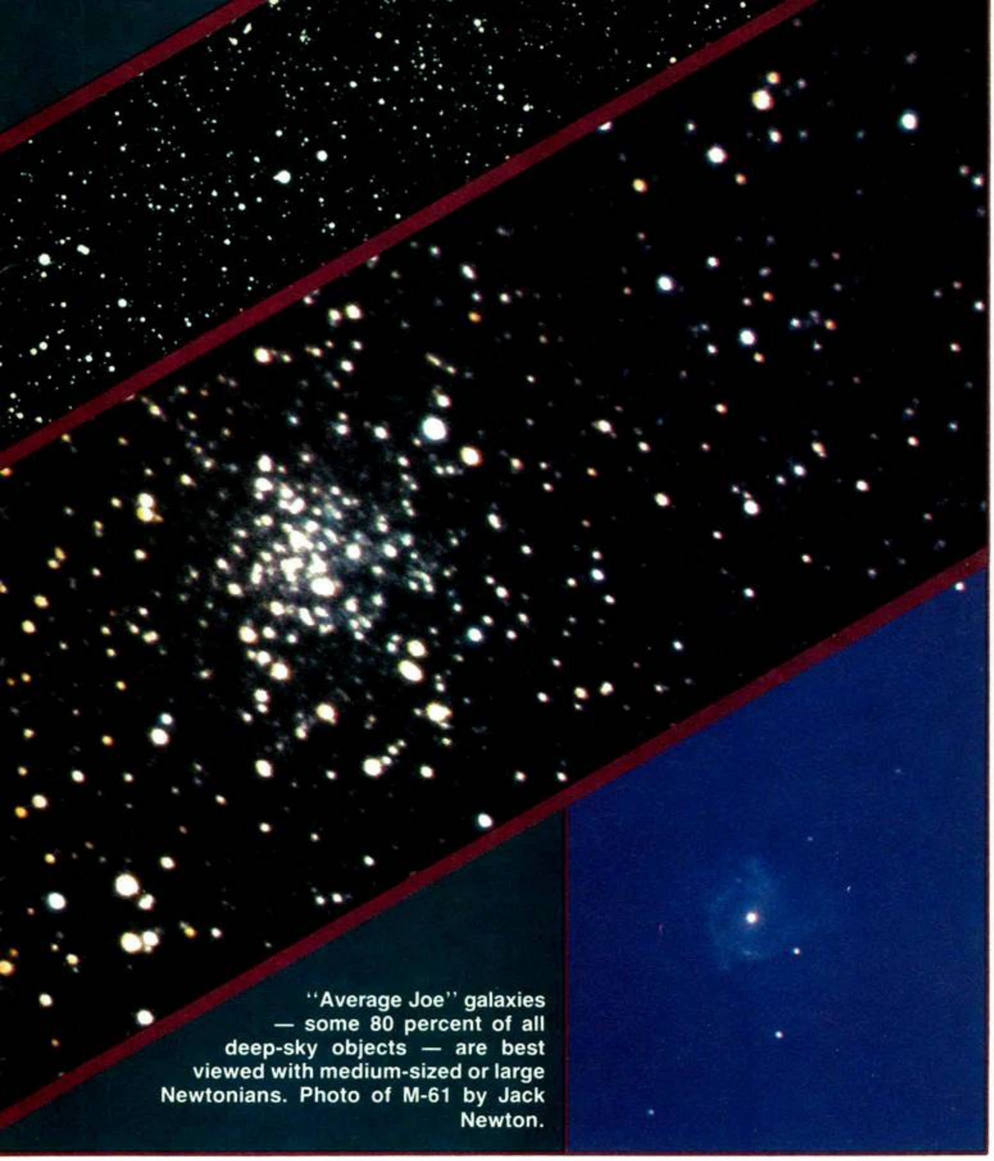
You can also use a compound Schmidt-Cassegrain or Maksutov-Cassegrain instrument, but these compound systems, which utilize lenses and mirrors, normally have high focal ratios of f/10 to f/15, giving them relatively high magnification, and therefore, dim images. The solution is to obtain large, long-focus eyepieces that will give low power, or you can add a focal reducing lens, which halves effective focal ratios and increases the area of the field by a factor of four. With a good focal reducer, 8-inch f/10 instruments with 80" focal lengths become 8-inch f/5 scopes with enough field to show an entire half of the Veil Nebula in one shot. Refractors, the classic long tubes with a lens at one end and eyepiece at the other, have the same problem with large, faint objects. Once again the problem is getting a suitably low magnification. We'll talk more about SCTs and refractors later.

### Variable Stars

If you are a variable star observer, you generally want a large field of view, but you also want good definition in star images. Most telescopes do an adequate job of showing off variable stars; a 4-inch f/10 reflector will allow you to follow all of the brighter long-period variables, semi-regulars, and a handful of Cepheids and irregular nova-like stars. An 8-inch SCT will allow you to do the same — with the addition of showing fainter examples of each class of variable — but the mirror configurations of compound telescopes introduce a complication. Most variable star observers depend upon the detailed charts from the American Association of Variable Star Observers (AAVSO). These charts usually have south at top and west at left, which works correctly with refractors and simple reflectors. Many of the compound SCTs, however, include a "star diagonal" that introduces a left/right reversal, which makes using AAVSO charts a trying experience. For variable star observing, your best bet is again a Newtonian reflector, mounted either equatorially or Dobsonian-style.

### High-Resolution Objects

Another class of deep-sky object is the "High-Res" group — things that require clean, high-resolution optics and large image scale to be seen well. Included in this category are double stars, small planetary nebulae, globular clusters, and small, faint galaxies. These objects are on the opposite end of the scale from the Big, Faint Fuzzies, and correspondingly they have entirely different characteristics and observing requirements. In looking at double stars, for example, you'll occasionally want to split a 1.5 arc-second pair. Observers of galaxies know that large reflectors are often lost when it comes to



"Average Joe" galaxies — some 80 percent of all deep-sky objects — are best viewed with medium-sized or large Newtonians. Photo of M-61 by Jack Newton.

successfully looking at a close double — the images are often muddy, even if the mirror has thermally stabilized and the seeing is reasonably good. For high-resolution work you'll need an entirely new approach — the refractor or compound telescope. Refractors — especially in the 4-inch to 6-inch range — offer unequaled resolution, high-contrast images, and the ability to deliver a crisp image at high powers. This is important not only for double stars, but for relatively small details in relatively bright deep-sky objects. Suppose you want to use high power to resolve the edges of globular M-5, or try to spot the central star in the Dumbbell Nebula, M-27. There is no doubt that a refractor will give you the best, cleanest image of this kind of detail, though the limited aperture will not yield a bright image.

Small refractors are lightweight and very portable. Unlike the Newtonians, which have one open end, refractors are closed, self-contained units free of image-unsettling tube currents caused by convection. But inch for inch, refractors are very expensive: a 2.4-inch runs from $275 to $500 — half that of a large reflector that can show much fainter stuff. A 3-inch may cost $500 to $1000, and a 6-inch $3000 to $8000. The price for superb image definition, good contrast, and high resolution is indeed great. If you are not concerned with cost and want the best possible optics, maybe in the 3- to 6-inch range, you might consider a refractor with a set of quality low-power eyepieces, which will widen the field and permit spectacular views of large objects like the North America Nebula or the Beehive cluster in Cancer.

Compound telescopes — SCTs and Maksutovs — also have relatively high focal ratios, correspondingly small fields of view, and reasonably good definition. SCTs are optically arranged so that the light path is folded; the light enters through a thin corrector lens, hits the primary mirror, bounces to the backside of the corrector (where it hits a secondary mirror), and comes back again through a hole in the primary to an eyepiece.

Schmidt-Cassegrains have become the most popular backyard telescope during the last decade because of their great portability — one person can easily carry around an entire 8-inch scope, mount, and accessories. Compared to ordinary reflectors they are fairly expensive; an 8-inch SCT runs $1200. If you're interested in sheer portability, a Schmidt-Cassegrain may be the telescope for you.

Maksutov-Cassegrains are similar to SCTs but feature two mirrors and a thick, deeply curved correcting lens. They too are very compact, come in f/ratios of 10 to 15, and are fairly expensive inch for inch. Their optical quality may be somewhat above that of the SCTs. A 3.5 or 4-inch Maksutov costs between $400 and $2500. They offer crisp images, but not much light-gathering power for faint detail in objects.

The "new kid on the block" is the Schmidt-Newtonian — a Newtonian reflector with an added thin correcting plate to remove the aberrations of its spherical, rather than paraboloidal, primary mirror. The low focal ratios of these telescopes mean that they are not too impressive with small details in deep-sky objects like planetary nebulae and globular clusters, but they offer nice, wide fields of view for the larger objects. They are priced reasonably as compound scopes go.

### "Average Joe" Galaxies

There are indeed specialized types of deep-sky objects — small, faint objects, variable stars, large and dim targets — but what about the run-of-the-mill deep-sky objects? Is any type of telescope best suited to observing average galaxies and nebulae? If at all possible, go to a star party and look through a variety of types of telescopes before you decide what is right for you. No single telescope is best suited for all facets of deep-sky observing — much of it comes down to personal preference, to what you'll end up enjoying looking at the most.

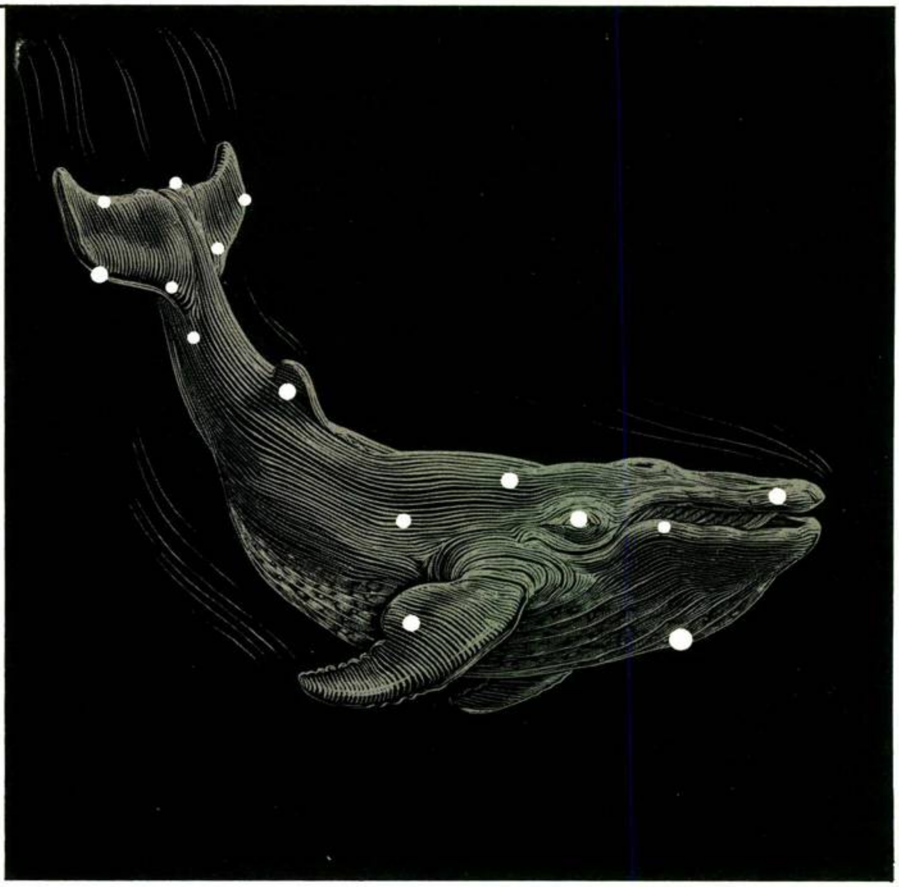
A word on astrophotography: sooner or later the odds are that you'll be bitten by the astrophotography "bug," and will want to try shooting exposures of the sky. Keep in mind when looking for a telescope that astrophotography requires a solid, well-tracking equatorial mount. You'll also need accessories such as a drive corrector, for making "fine tuning" tracking adjustments, and other specialized gear. Newtonian reflectors, either equatorial or Dobsonian, are clearly an intelligent choice for observing: they generally offer short focal ratios (which equal wide fields and bright images). They are relatively poor on resolution when compared with refractors, but they abound in light-gathering power. Much of deep-sky observing is gazing at galaxies at low power, which doesn't require the highest resolution. Newtonians are relatively inexpensive and offer large apertures for those who don't mind lugging around big telescopes. Who would have thought that the day would come when $1000 would buy a ticket to every single deep-sky object in the NGC? William Herschel would be proud indeed!

*— David J. Eicher*

Left: The bright galaxy M-77 is one of the best-known examples of a Seyfert galaxy, a system whose tiny core emits intense ultraviolet radition. The core, surrounded by a hazy envelope of nebulosity, is easily visible in small telescopes. Photo by Jack Newton. Below left: NGC-247 is a low-surface-brightness galaxy that is difficult to see in telescopes smaller than 6 inches in aperture. Photo by Martin C. Germano. Below right: One of the largest planetary nebulae in the sky, NGC-246 appears as a ghostly incomplete ring of nebulosity; its central star glows at 12th magnitude. Photo by Bill Iburg.

# Cetus

## Cet
## Ceti



Keith Ward

**Cetus** the Whale, a relatively barren constellation lying south of Pisces in the great void of the autumn sky, is home to a collection of some of the finest and most unusual galaxies in the sky. Although it is primarily known for the variable star Mira, and otherwise appears dull to the naked-eye viewer, Cetus offers a nice selection of telescopic objects for those who wish to seek them out.

A first stop in Cetus is the famed star **Mira**, Omicron (ο) Ceti, the prototype of the so-called long-period variables. Mira means "the wonderful," an appropriate name since it was the first variable star to be discovered (although the name predates the discovery); the feat was accomplished by the German astronomer David Fabricius in 1596. Mira normally fluctuates between about ninth magnitude and third magnitude over a period of about 331 days; sometimes it reaches second magnitude at maximum and the period is slightly longer or shorter, but the star is bright and predictable enough that its changes are easy to follow in a telescope or binoculars.

Mira lies at a distance of about 70 parsecs and, like all long-period variables (LPVs), is an old red giant star believed to pulsate, since its physical characteristics seem to change throughout the cycle of its variations. Astronomers believe the pulsations arise from changes in the aging star's energy-producing core.

A close, bright double star in Cetus is **Gamma (γ) Ceti**, whose components shine at magnitudes 3.6 and 6.2 with a mere 2.7 arc-second separation. A good 3-inch refractor will split the two stars without too much trouble, providing the seeing is steady. The primary is a type A2 main sequence star, while the companion is a type F3 dwarf; they are sometimes described as being bluish and yellowish in the telescope — perhaps simply a contrast effect. A third physically connected companion lies some 14′ to the northwest — it is an M-type dwarf called BD +2° 418, and shines at 10th magnitude.

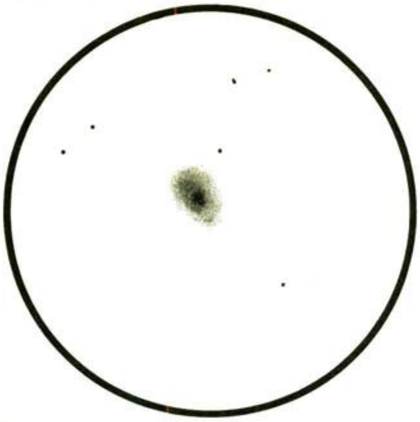
Located roughly midway between Gamma and Omicron Ceti are a few notable galaxies. The compact galaxy **M-77** (NGC-1068) — found about 1° southeast of Delta (δ) Ceti — shines at magnitude 9.6 and measures 2.5′ x 1.7′ across, making it an easy target for small telescopes. In a 2.4-inch refractor it appears as a condensed ball of fuzzy light. A 4-inch scope at high power shows a clearly defined circular "disk" as well as a much dimmer outer halo of nebulosity. M-77 is a Seyfert galaxy, one of the curious systems discovered by the American astronomer Carl Seyfert and catalogued for their intense and variable ultraviolet emission. A 10-inch telescope at high power shows a tiny bright nucleus — the source of the high-energy radiation — embedded within the galaxy's center. M-77 is classed as an Sb-type spiral, holds around 100 billion solar masses, and measures 30 kiloparsecs across. M-77 was one of two galaxies in which large redshifts were first detected, by Vesto M. Slipher in 1913. (The other galaxy was M-104, the "Sombrero.")

Lying at a distance of about 11.8 megaparsecs, M-77 is the chief member of a small group of galaxies that also includes **NGC-1055**. This is an Sb-type system much like the Milky Way, but seen edge-on; its broad equatorial dust lane is visible in large amateur telescopes. Small backyard telescopes show NGC-1055 as a slender streak of misty light, spanning some 5.0′ x 1.0′ and glowing at magnitude 11.4. A possible member of the M-77 group is the face-on barred spiral system **NGC-1073**, which shines at magnitude 11.5 but has a low surface brightness because its light is spread over a circular area 4′ across. Photographs of this galaxy show unusual knotty structure in the arms; with the aid of a nebular filter, a large telescope may just be capable of revealing some of this detail. Most telescopes show NGC-1073 as a large glow with a slightly brighter middle, and little definition.

Lying in the western part of Cetus is the large, irregular galaxy **IC 1613**. This is a difficult object for small telescopes, as its integrated magnitude of 12.0 is spread over the large area of 11.0′ x 9.0′, resulting in a very low surface brightness. Under perfect skies, large binoculars or RFTs show IC 1613 as a dim wispy glow — but under average conditions a 6-inch or 8-inch scope is the minimum needed to show the object. IC 1613 lies at nearly the same distance as the M-31 group —

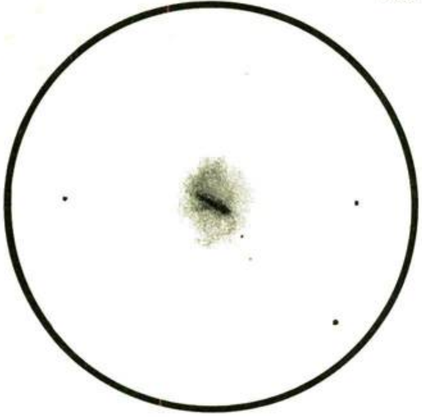
For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

**M-77**



**NGC-1073**

8-inch f/10
SCT
70X



Sketches by David J. Eicher

680 kiloparsecs — comfortably earning its membership in the Local Group of galaxies, which extends out to at least 1 megaparsec from the Milky Way.

South of IC 1613 are a variety of objects, one of which is the small spiral galaxy **NGC-157**. This galaxy is one of the "many-armed spirals": Sc-type loosely wrapped galaxies with a proliferation of spiral arms (it has five or six). NGC-157 measures 2.8′ x 2.1′ across and shines at 11th magnitude, making it easy to spot as a nebulous patch in a 3-inch telescope. Large backyard scopes begin to show a knotty structure amidst the halo, but the detail is pretty faint and elusive.

A few degrees southeast of NGC-157 is **NGC-246**, one of the largest planetary nebulae in the sky: this nebula sports an apparent diameter of 240″ x 210″, over which it spreads a photographic magnitude of 8.0. It has a relatively low surface brightness, but it takes magnification well enough to show considerable structure over its face. NGC-246 is basically ring-shaped with localized spots of brighter and fainter light that give it a strangely uneven appearance. Within NGC-246's ring of nebulosity lie four bright stars; the most centrally located is the illuminating star, which shines at 12th magnitude. An 8-inch reflector at 100x easily shows all of the stars inside, as well as the ring, which appears incomplete since it is faintest toward the southeast.

The largest galaxy in Cetus is the highly inclined spiral **NGC-247**, which spans 18.0′ x 5.0′ and shines at magnitude 9.5. To find NGC-247, which is of very low surface brightness, look 3° south-southeast of the bright star Beta (β) Ceti. This galaxy is classed as a type Sc spiral, though the arms show weakly and the outer envelope appears to be made up of irregular patches of stars and gas. NGC-247 is a member of the Sculptor group of galaxies, which also includes the bright objects NGC-45, NGC-55, NGC-253, NGC-300, and NGC-7793. At a distance of 2.4 megaparsecs, these galaxies are the closest to us with the exception of those in our own Local Group. **NGC-45**, a spiral galaxy that measures 8.0′ x 5.5′ and glows at magnitude 11.1, also lies in Cetus. It is rather more difficult than NGC-247, but is nevertheless visible in small apertures as an oval-shaped blob of light with a bright middle. An eighth-magnitude star lies 4.5′ southwest of this galaxy.

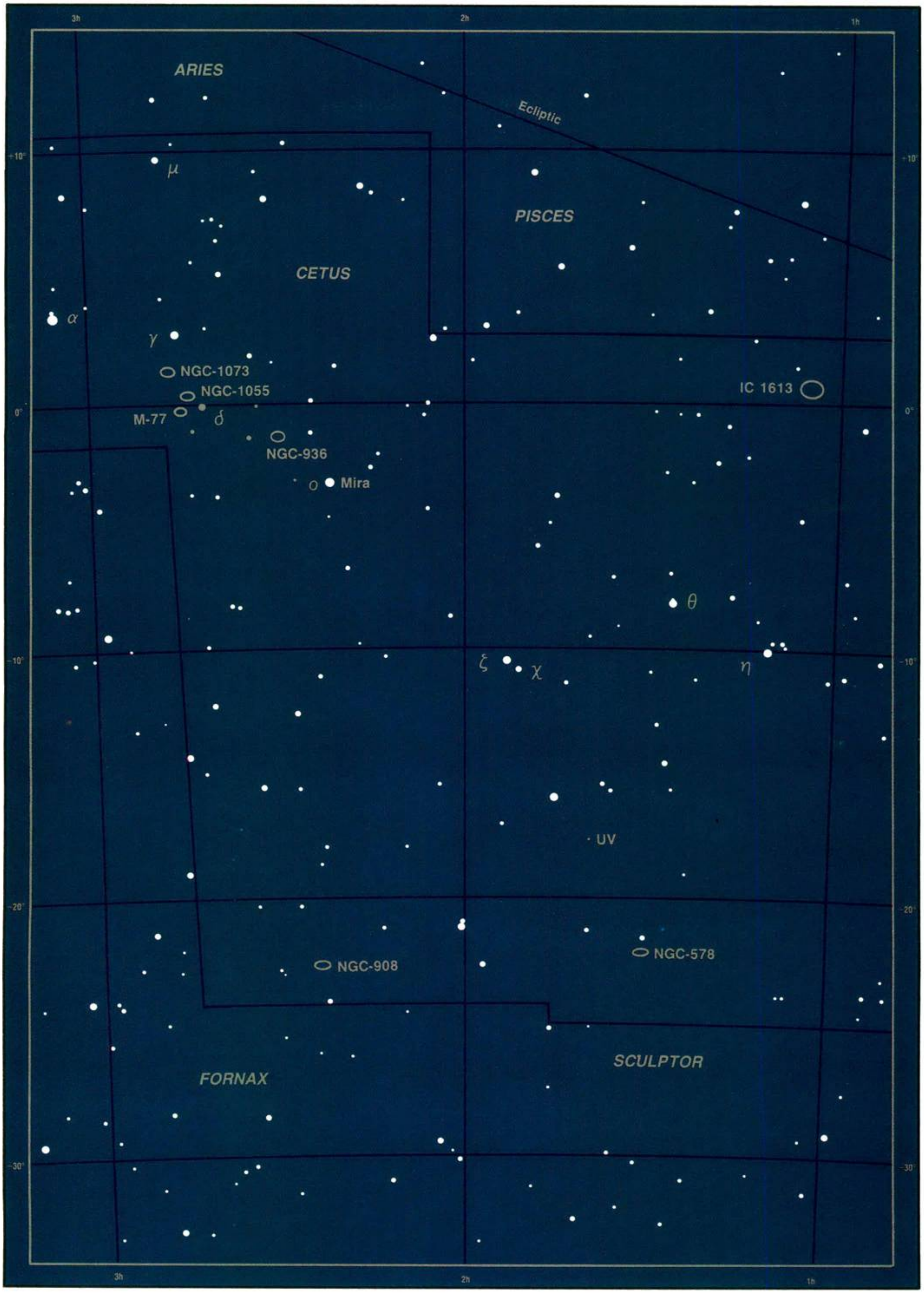
A few more bright galaxies lie in Cetus, out in the central region of the Whale. One such object is the 12th magnitude Sc-type spiral **NGC-578**, easily visible as a roundish patch of mottled haze in telescopes of 4- or 5-inch aperture. The object measures 4.5′ x 2.5′ in diameter and has a relatively condensed nuclear region. NGC-578's integrated magnitude is about 11.5, making it visible in large finderscopes as a small nebulous patch. **NGC-908** is another late-type spiral, which shows prominently loose spiral arms — visible as a mottled area of uneven texture in telescopes in the 10-inch to 20-inch aperture range. This galaxy has a magnitude of 10.9 and measures 4.0′ x 2.5′ across, making it just a bit brighter than NGC-578. The galaxy **NGC-936** is a fine barred spiral, showing a nebulous knot in its center surrounded by a faint haze. Its magnitude of 11.2 is spread over an area of 3.0′ x 2.0′, keeping its surface brightness relatively high. The Sc-type spiral **NGC-941**, a 13th magnitude object, lies 12′ to the west.

Let's finish our tour of Cetus with a look at one of the closest stars to the Sun. At a distance of 2.8 parsecs, **UV Ceti** is a system comprised of two of the smallest and faintest stars known. Discovered by the American astronomer W.J. Luyten in 1949, the system consists of magnitude 12.4 and 13.0 stars, and has the unusually high proper motion of 3.35 arc-seconds per year, in position angle 80°. Each of these two stars has only about eight percent of the Sun's mass. The variable star designation applies to the fainter of the two, whose violent radio and optical flares are typically 100 to 1000 times more powerful than those from our Sun.

| Object | M# | Type | R.A. (2000) | Dec. | Mag. | Size/Sep./Per. | H |
|---|---|---|---|---|---|---|---|
| NGC-45 | | § | 0h 13.9m | −23°10′ | 11.1 | 8.0′x5.5′ | Scd |
| NGC-157 | | § | 0h 34.7m | − 8°23′ | 11.0 | 2.8′x2.1′ | Sc |
| NGC-246 | | ■ | 0h 47.2m | −11°53′ | 8.0 | 240″x210″ | |
| NGC-247 | | § | 0h 47.2m | −20°45′ | 9.5 | 18.0′x5.0′ | Sc |
| IC 1613 | | §I | 1h 05.1m | +01°18′ | 12.0 | 11.0′x9.0′ | I |
| NGC-578 | | § | 1h 30.4m | −22°41′ | 11.5 | 4.5′x2.5′ | Sc |
| UV | | IV | 1h 38.8m | −17°58′ | 7↔12 | Irr | |
| Omicron (ο) | | LPV | 2h 19.3m | −02°58′ | 3↔9.5 | 331d | |
| NGC-908 | | § | 2h 23.1m | −21°13′ | 10.9 | 4.0′x1.3′ | Sc |
| NGC-936 | | §B | 2h 27.6m | −01°09′ | 11.2 | 3.0′x2.0′ | SB0 |
| NGC-1055 | | § | 2h 41.8m | +00°29′ | 11.4 | 5.0′x1.0′ | Sbc |
| NGC-1068 | M-77 | § | 2h 42.7m | −00°01′ | 9.6 | 2.5′x1.7′ | Sb |
| Gamma (γ) | | ★$^2$ | 2h 43.3m | +03°15′ | 3.5,6.0 | 2.7″ | |
| NGC-1073 | | §B | 2h 43.8m | +07°23′ | 11.5 | 4.0′x4.0′ | SBc |

**H = Hubble classification type for galaxies**

| | |
|---|---|
| ★$^2$ | *Double Star* |
| LPV | *Long Period Variable* |
| IV | *Irregular Variable* |
| ■ | *Planetary Nebula* |
| § | *Spiral Galaxy* |
| §B | *Barred Spiral Galaxy* |
| §I | *Irregular Galaxy* |


3h
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ARIES
Ecliptic
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NGC-1055
IC 1613
M-77
δ
0°
NGC-936
ο
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ζ
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UV
-20°
NGC-578
NGC-908
SCULPTOR
FORNAX
-30°
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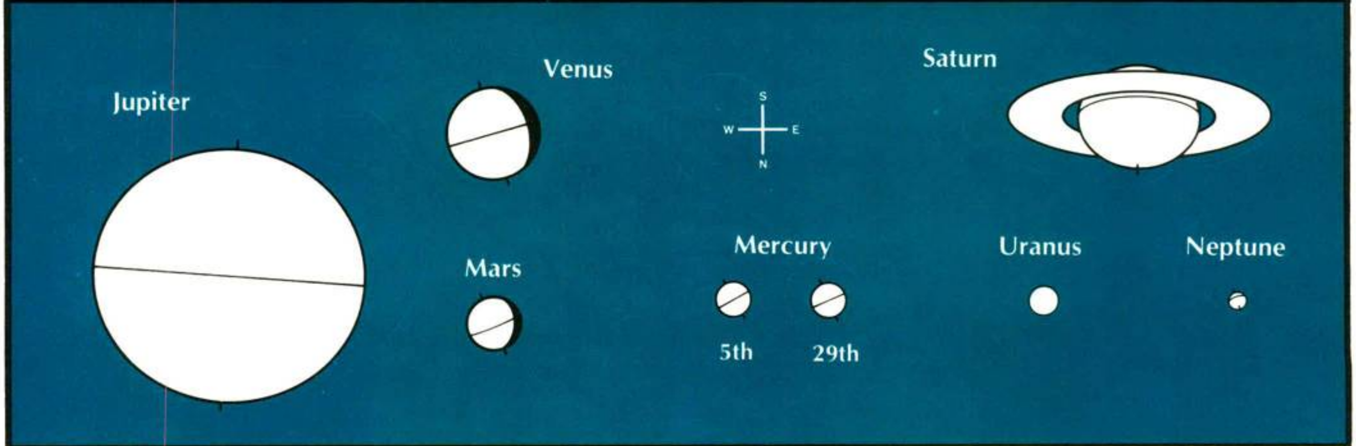
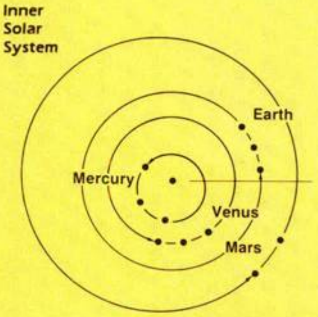
1h

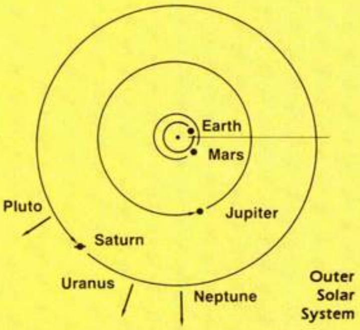
# Planetary Data

# October 1984


Jupiter
Venus
Saturn
S
W
E
N
Mars
Mercury
Uranus
Neptune
5th
29th

| | | | | Angular | % | Distance (AU) from: | | Longitude: | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Date | Mag. | Size | Illum. | Earth | Sun | Heliocentric | Ecliptic | R.A. (2000.0) | Dec. |
| **Sun** | | 1 | −26.7 | 32.0′ | — | 1.00 | — | — | 188°00.1′ | 12h 30.1m | −3°15.3′ |
| | | 15 | −26.7 | 32.1′ | — | 1.00 | — | — | 201°49.3′ | 13h 21.4m | −8°34.8′ |
| | | 31 | −26.8 | 32.3′ | — | 0.99 | — | — | 217°45.4′ | 14h 22.4m | −14°09.9′ |
| **Mercury** | ☿ | 1 | −1.3 | 5.1″ | 96% | 1.32 | 0.40 | 158°22.3′ | 179°51.1′ | 12h 04.8m | 1°25.3′ |
| | | 15 | −1.2 | 4.7″ | 100% | 1.43 | 0.43 | 211°49.6′ | 204°19.4′ | 13h 33.7m | −9°08.9′ |
| | | 31 | −0.5 | 4.9″ | 94% | 1.38 | 0.47 | 257°51.2′ | 229°47.4′ | 15h 10.9m | −19°00.4′ |
| **Venus** | ♀ | 1 | −3.9 | 11.7″ | 88% | 1.43 | 0.73 | 257°43.5′ | 216°02.9′ | 14h 17.6m | −13°47.9′ |
| | | 15 | −4.0 | 12.3″ | 85% | 1.35 | 0.73 | 279°54.1′ | 233°08.6′ | 15h 25.0m | −19°26.1′ |
| | | 31 | −4.0 | 13.3″ | 81% | 1.26 | 0.73 | 305°12.0′ | 252°35.9′ | 16h 46.7m | −23°51.8′ |
| **Mars** | ♂ | 15 | 0.4 | 7.5″ | 86% | 1.25 | 1.39 | 320°58.0′ | 276°20.7′ | 18h 31.1m | −25°17.8′ |
| **Jupiter** | ♃ | 15 | −2.1 | 36.7″ | 99% | 5.36 | 5.18 | 286°59.1′ | 275°50.3′ | 18h 28.4m | −23°25.7′ |
| **Saturn** | ♄ | 15 | 0.6 | 15.3″ | 100% | 10.80 | 9.89 | 228°14.0′ | 225°23.7′ | 14h 56.9m | −14°40.1′ |
| **Uranus** | ⛢ | 15 | 5.7 | 3.6″ | 100% | 19.68 | 19.04 | 253°11.2′ | 250°32.3′ | 16h 38.2m | −22°06.1′ |
| **Neptune** | ♆ | 15 | 8.0 | 2.2″ | 100% | 30.63 | 30.26 | 270°44.3′ | 268°36.0′ | 17h 56.6m | −22°17.7′ |
| **Pluto** | ♇ | 15 | 13.8 | 0.1″ | 100% | 30.74 | 29.80 | 212°00.5′ | 211°12.4′ | 14h 21.1m | 3°10.1′ |

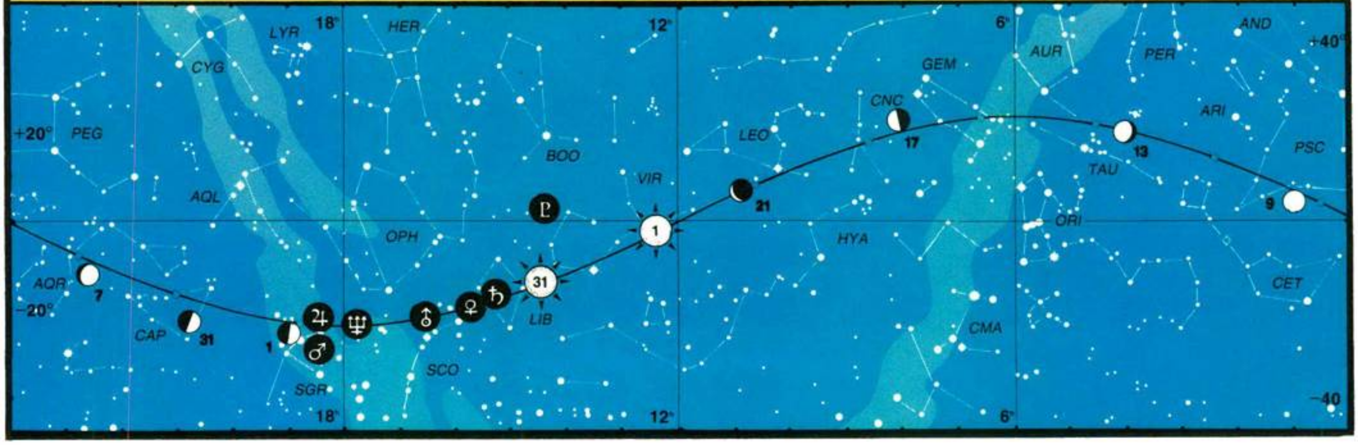

Inner
Solar
System
Earth
Mercury
Venus
Mars


Earth
Mars
Pluto
Jupiter
Saturn
Uranus
Neptune
Outer
Solar
System

## Moon Data

First Quarter . . . . . . . . . . . . Oct. 1 at 21:52
Full Moon . . . . . . . . . . . . . . Oct. 9 at 23:58
Last Quarter . . . . . . . . . . . . Oct. 17 at 21:14
New Moon . . . . . . . . . . . . Oct. 24 at 12:08
First Quarter . . . . . . . . . . . . Oct. 31 at 13:07
Full Moon . . . . . . . . . . . . . . Nov. 8 at 17:43

Apogee: Oct. 8 at 14:45 . . . . . 406,315 km.
Perigee: Oct. 23 at 13:50 . . . . . 358,507 km.


LYR
18h
HER
12h
CYG
6h
GEM
AUR
AND
PER
+40°
CNC
ARI
+20°
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13
TAU
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BOO
VIR
AQL
21
ORI
9
♇
OPH
1
HYA
31
AQR
7
♄
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⛢
♆
♃
♂
LIB
CET
−20°
CAP
31
1
CMA
SCO
SGR
18h
12h
6h
−40

**Last June 25th, Jupiter lay just to the north of the globular cluster M-22 in Sagittarius. Using a 10-inch f/5 Newtonian and VR1000 film, Tim Pickering took this photo, which shows the cluster, Jupiter, and several jovian moons. This month, Jupiter will pass even closer to M-22 — see the "Jupiter" section on page 84.**

### Mercury

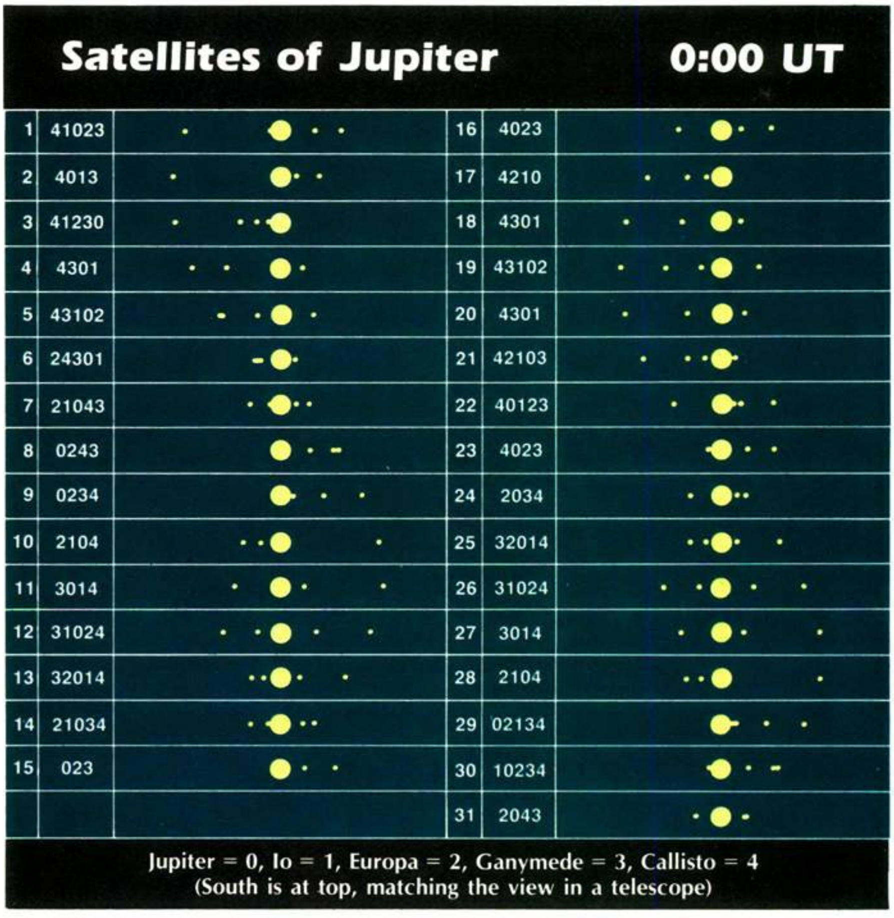
Mercury appeared briefly in the morning sky in September, but disappeared from view by the end of the month. It passes through superior conjunction on October 10th and won't be visible in the evening sky until the middle of November.

### Venus

Venus gains slowly in visibility during October evenings. Its brightness increases slightly, and in your telescope its disk will become somewhat more gibbous (from 88% lit on the 1st to about 80% on the 31st). Your best views of Venus will come on the evenings of the 7th and 8th, when Venus will lie less than a degree away from 2.9 magnitude Alpha (α) Librae and about 2½° from Saturn. Use your lowest-power eyepiece.

On the 27th at around 1h UT, a 2.5 day old crescent Moon will occult Venus as seen from Japan, the northern Pacific, and Central America. A little later in the month, Venus passes 1° 27′ south of Uranus at 23:33 UT on the 29th. Both will

## Satellites of Jupiter 0:00 UT



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|---|---|---|---|
| 1 | 41023 | 16 | 4023 |
| 2 | 4013 | 17 | 4210 |
| 3 | 41230 | 18 | 4301 |
| 4 | 4301 | 19 | 43102 |
| 5 | 43102 | 20 | 4301 |
| 6 | 24301 | 21 | 42103 |
| 7 | 21043 | 22 | 40123 |
| 8 | 0243 | 23 | 4023 |
| 9 | 0234 | 24 | 2034 |
| 10 | 2104 | 25 | 32014 |
| 11 | 3014 | 26 | 31024 |
| 12 | 31024 | 27 | 3014 |
| 13 | 32014 | 28 | 2104 |
| 14 | 21034 | 29 | 02134 |
| 15 | 023 | 30 | 10234 |
| | | 31 | 2043 |

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

**Right: Omega Centauri is perhaps the most striking globular cluster in the sky. October's "Best Astro-Photo" award goes to Jim Barclay of Manly, Queensland, Australia, who used a 12½-inch f/6 scope and a 15-minute exposure on VR1000 to film it. Left: barred spiral galaxy NGC-1097 in Fornax. Photo by Ben Negy, Jr.**

be low in the southwest, and, again, a low-power eyepiece will show them best.

### Mars

As with Venus, the visibility of Mars in the evening sky increases slightly this month. Its southward motion in declination "bottoms out" and begins to climb northward, and the early sunsets leave Mars slightly higher each evening. Its disk measures only 7.5" of arc across, and we are looking down upon the martian equatorial regions.

There are plenty of conjunctions in store this month for the Red Planet: Mars passes south of Neptune (on the 3rd at 13:27 UT, 3° 18′ separation), Jupiter (13th, 23:05 UT, 1° 54′), and north of Lambda (λ) Sagittarii (14th, 00:09 UT, 5′). On the 16th, it will pass south of the center of the globular cluster M-22 (16:44 UT, 1° 17′). Mars also passes south of the stars SAO 187216 (magnitude 5.8) and SAO 187883 (6.2) on the 19th and 29th, respectively. The event on the 19th occurs at 9:36 UT, that on the 29th at 3:16 UT. In both cases, Mars misses the star by about 2 arc-minutes.

### Asteroids

1 Ceres (magnitude 7.5) is retrograding in southwestern Taurus near the border with Cetus and Aries. Its positions:

9th: 3h 38m 27s, 9° 38.3′
19th: 3h 32m 56s, 9° 22.6′

Ceres rises about 8:30 p.m. local daylight time on the 15th.

2 Pallas (9.1) is moving southwestward in central Aquarius. Its positions:

9th: 22h 27m 23s, −4° 41.7′
19th: 22h 24m 41s, −6° 27.7′

Pallas transits the meridian around 10 p.m. local daylight time at mid-month.

3 Juno (10.5) passes from Sextans into southwestern Leo during October. Its positions:

9th: 10h 55m 00s, 3° 21.5′
19th: 11h 10m 31s, 2° 04.6′

Juno rises at 3 a.m. local daylight time on the 15th.

4 Vesta (8.2) is moving parallel to Juno, but about 10° to the northeast. During October, it passes out of Leo into Virgo. At 1:51 UT on the 27th, Vesta will lie 4′ 49″ south of 4.2 magnitude Nu (ν) Virginis. Vesta's positions:

9th: 11h 13m 36s, 9° 23.0′
19th: 11h 31m 7s, 7° 48.1′

Vesta rises about 4:30 a.m. local daylight time at mid-month.

For convenience in plotting the positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

### Jupiter

As noted above, Jupiter will have a conjunction with Mars on the 13th, but this isn't Jupiter's only meeting. Around 14h UT on the 27th, Jupiter will pass about 35′ north of the center of the bright globular cluster M-22. Since Jupiter moves slowly, its approach to the cluster and departure will be well worth watching over about a two-week period centered on the 27th. Use a low-power eyepiece.

### Saturn

On October 1st, Saturn will have a 10° elevation in the southwestern sky, 45 minutes after sunset; by month's end, it will be too close to the Sun to be seen.

### Uranus

Uranus' motion eastward is taking it away from its "guide star" Antares, but the tilt of the ecliptic as the two set in the evening sky places Uranus almost directly above Antares relative to the horizon.

To locate Uranus this way, go out 45 minutes after sunset and center your scope on Antares. Then offset a degree to the left and sweep slowly upward a distance of 4½°. Uranus should be in your field of view or very close to it. Use low power to scan and then switch to medium powers to discern Uranus' 3.6" of arc disk.

### Neptune

The "guide post" for Neptune is M-20, the Trifid Nebula. Again, 45 minutes after sunset, go out and locate the nebula by scanning north from the spout of Sagittarius' Teapot. Then scan about 15′ up and 1.5° to the right. Neptune has a disk 2.2" across and of 8.0 magnitude.

### Meteors

October's meteor showers include the Draconids and the Orionids. This year, unfortunately, the Moon interferes with both: it is Full for the Draconids on the 9th, and waning crescent for the Orionids on the 20th.

The Draconids produce highly variable numbers, with displays generally poor except when the parent comet (P/Giacobini-Zinner) is near perihelion, which occurs next year. With a Full Moon and an off year, the numbers will probably be scant — perhaps 10 per hour coming from the head of Draco.

The Orionids' parent is Comet Halley, which should be visible, at least in medium to large telescopes, by this time next year. The Halley Watch organizers would like to have accurate observations of this last pre-return Orionid apparition, so try to observe on as many nights and early mornings as you can for about a week before and after the 20th. Get report forms (visual and photographic) from the International Halley Watch, Jet Propulsion Laboratory, Mail Stop T-1166, 4800 Oak Grove Drive, Pasadena, CA 91109.

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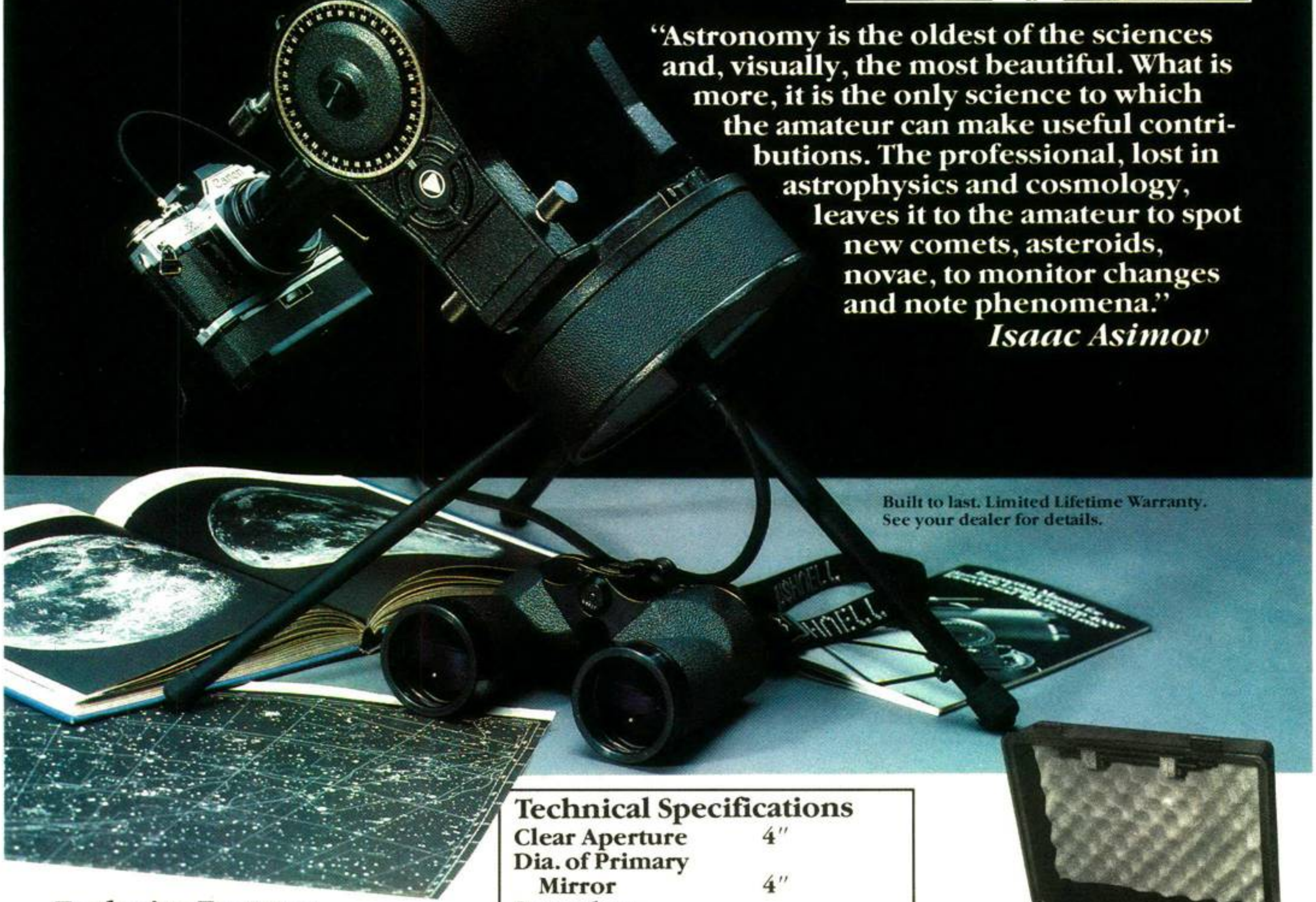
*Isaac Asimov*



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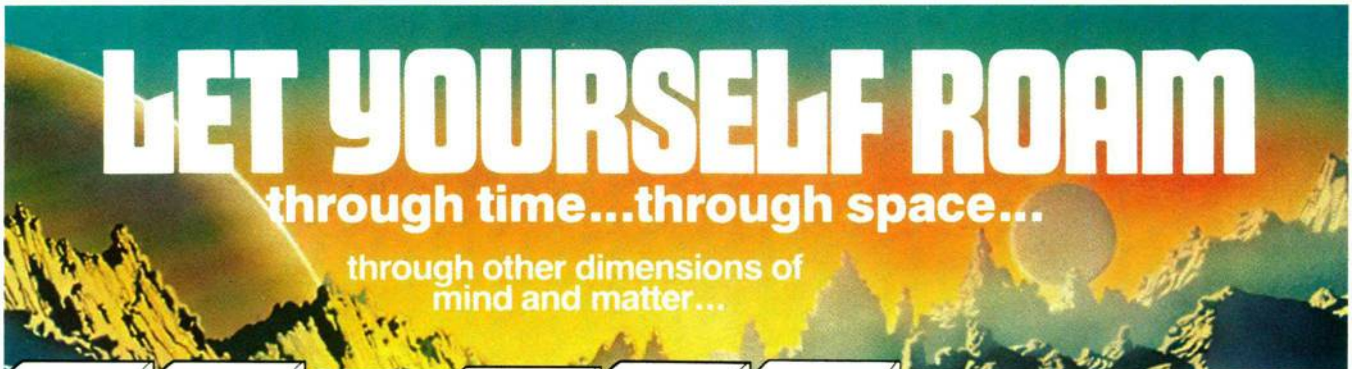
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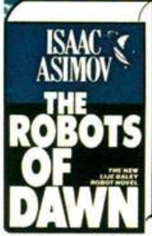
through other dimensions of mind and matter...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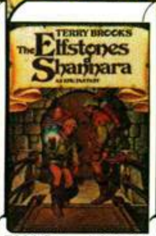
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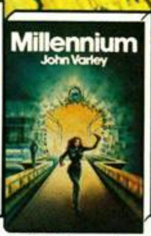
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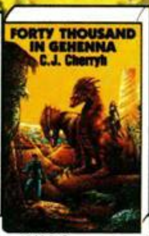
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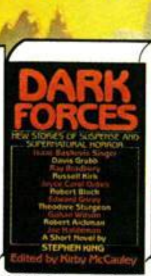
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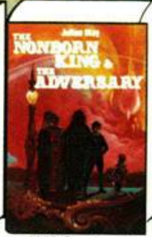
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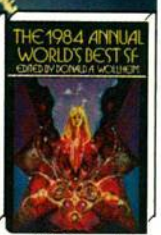
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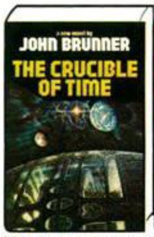
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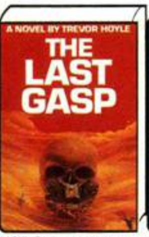
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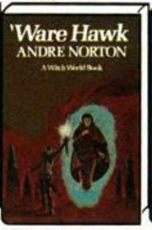
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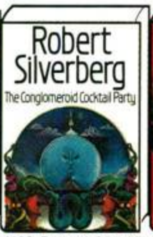
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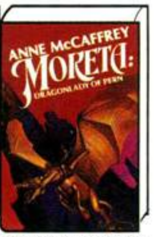
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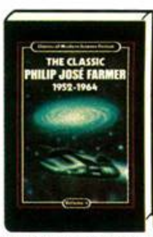
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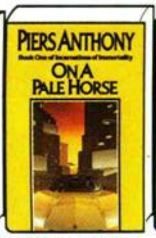
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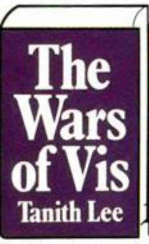
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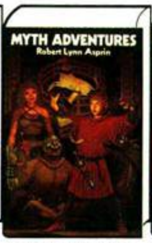
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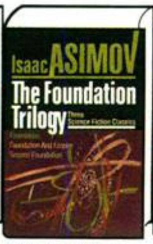
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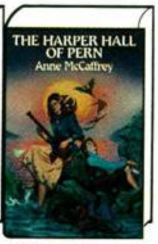
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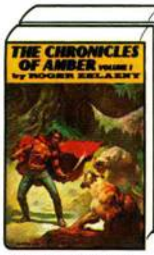
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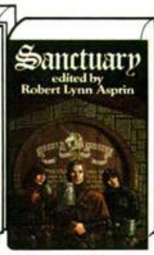
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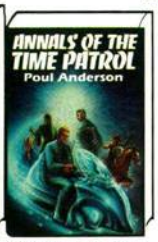
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